9

Thermal Properties of Matter

Numerical

Q.1. There is an air bubble of radius 1.0 mm in a liquid of surface tension 0.075 Nm−1 and density 1000 kg m−3 at a depth of 10 cm below the free surface. The amount by which the pressure inside the bubble is greater than the atmospheric pressure is ________

JEE Main 2023 (Online) 15th April Morning Shift

Q.2. The elastic potential energy stored in a steel wire of length 20 m stretched through 2 cm is 80 J. The cross-sectional area of the wire is _________ mm2.

JEE Main 2023 (Online) 13th April Morning Shift

Q.3. Glycerine of density 1.25×103 kg m−3 is flowing through the conical section of pipe The area of cross-section of the pipe at its ends are 10 cm2 and 5 cm2 and pressure drop across its length is 3 Nm−2. The rate of flow of glycerin through the pipe is x×10−5 m3 s−1. The value of x is __________.

JEE Main 2023 (Online) 12th April Morning Shift

Q.4. The surface tension of soap solution is 3.5×10−2 Nm−1. The amount of work done required to increase the radius of soap bubble from 10 cm to 20 cm is ________ × 10−4 J

JEE Main 2023 (Online) 11th April Evening Shift

Q.5. A wire of density 8×103 kg/m3 is stretched between two clamps 0.5 m apart. The extension developed in the wire is $3.2\times10-4$ m. If $Y=8\times1010$ N/m2, the fundamental frequency of vibration in the wire will be __________ Hz.

JEE Main 2023 (Online) 11th April Evening Shift

Q.6. The length of a wire becomes l1 and l2 when 100 N and 120 N tensions are applied respectively. If 10 l2=11 l1, the natural length of wire will be 1/x l1. Here the value of x is

____________.

JEE Main 2023 (Online) 11th April Morning Shift

Q.7. Figure below shows a liquid being pushed out of the tube by a piston having area of cross section 2.0 cm2. The area of cross section at the outlet is 10 mm2. If the piston is pushed at a speed of 4 cm s−1, the speed of outgoing fluid is

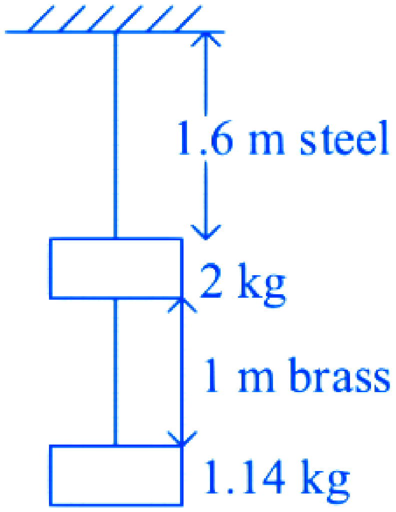
_________ cms^{-1}

JEE Main 2023 (Online) 10th April Evening Shift

Q.8. Two wires each of radius 0.2 cm and negligible mass, one made of steel and the other made of brass are loaded as shown in the figure. The elongation of the steel wire is

_________ × 10−6 m. [Young's modulus for steel =

2 × 1011 Nm−2 and g = 10 ms−2]



JEE Main 2023 (Online) 10th April Morning Shift

Q.9. A steel rod of length 1 m and cross-sectional area 10−4 m2 is heated from 0∘C to 200∘C without being allowed to extend or bend. The compressive tension produced in the rod is __________ ×104 N. (Given Young's modulus of steel =2×1011Nm−2, coefficient of linear expansion =10−5 K−1)

JEE Main 2023 (Online) 8th April Evening Shift

Q.10. An air bubble of diameter 6 mm rises steadily through a solution of density 1750 kg/m3 at the rate of 0.35 cm/s. The co-efficient of viscosity of the solution (neglect density of air) is __________ Pas (given, g=10 ms−2).

JEE Main 2023 (Online) 8th April Morning Shift

Q.11. A metal block of mass m is suspended from a rigid support through a metal wire of diameter 14 mm. The tensile stress developed in the wire under equilibrium state is 7×105Nm−2. The value of mass m is ________ kg. (Take, g=9.8 ms−2 and π=22/7)

JEE Main 2023 (Online) 6th April Evening Shift

Q.12. A steel rod has a radius of 20 mm and a length of 2.0 m. A force of 62.8 kN stretches it along its length. Young's modulus of steel is 2.0×1011 N/m2. The longitudinal strain produced in the wire is ___________ $\times 10^{-5}$

JEE Main 2023 (Online) 6th April Morning Shift

Q.13. The surface of water in a water tank of cross section area 750 cm2 on the top of a house is h m above the tap level. The speed of water coming out through the tap of cross section area 500 mm2 is 30 cm/s. At that instant, dh/dt is x×10−3 m/s. The value of x will be __________.

JEE Main 2023 (Online) 1st February Evening Shift

Q.14. A certain pressure 'P' is applied to 1 litre of water and 2 litre of a liquid separately. Water gets compressed to 0.01% whereas the liquid gets compressed to 0.03%. The ratio of Bulk modulus of water to that of the liquid is 3/x. The value of x is __________.

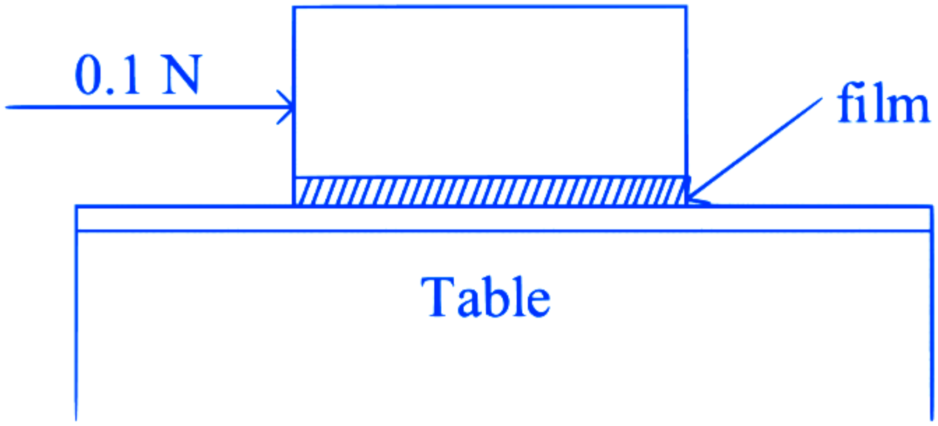
JEE Main 2023 (Online) 1st February Morning Shift

Q.15. A thin rod having a length of 1 m and area of cross-section 3×10−6 m2 is suspended vertically from one end. The rod is cooled from 210◦C to 160◦C. After cooling, a mass M is attached at the lower end of the rod such that the length of rod again becomes 1 m. Young's modulus and coefficient of linear expansion of the rod are 2×1011 N m−2 and 2×10−5 K−1, respectively. The value of M is _________ kg.

(Take g=10 m s^{-2})

JEE Main 2023 (Online) 31st January Morning Shift

Q.16. A metal block of base area 0.20 m2 is placed on a table, as shown in figure. A liquid film of thickness 0.25 mm is inserted between the block and the table. The block is pushed by a horizontal force of 0.1 N and moves with a constant speed. IF the viscosity of the liquid is 5.0×10−3 Pl, the speed of block is __________ ×10−3 m/s.

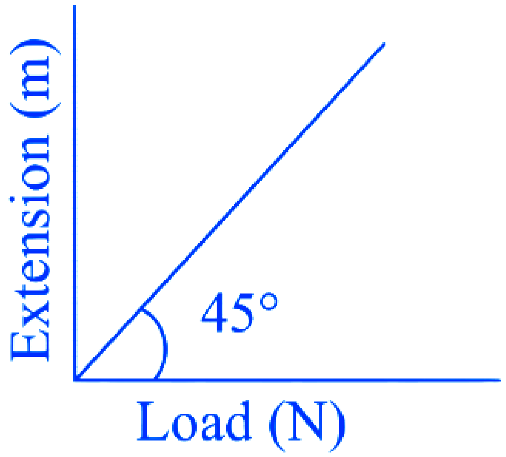


JEE Main 2023 (Online) 29th January Evening Shift

Q.17. A spherical drop of liquid splits into 1000 identical spherical drops. If ui is the surface energy of the original drop and uf is the total surface energy of the resulting drops, the (ignoring evaporation $\frac{u_f}{u_i} = \left(\frac{10}{x}\right)$. Then value of x is __________:

JEE Main 2023 (Online) 25th January Evening Shift

Q.18. As shown in the figure, in an experiment to determine Young's modulus of a wire, the extension-load curve is plotted. The curve is a straight line passing through the origin and makes an angle of 45∘ with the load axis. The length of wire is 62.8 cm and its diameter is 4 mm. The Young's modulus is found to be x×104 Nm−2. The value of x is __________.



JEE Main 2023 (Online) 25th January Morning Shift

Q.19. A Spherical ball of radius 1mm and density 10.5 g/cc is dropped in glycerine of coefficient of viscosity 9.8 poise and density 1.5 g/cc. Viscous force on the ball when it attains constant velocity is $3696\times10^{-\pi}$ N. The value of x is (Given, g = 9.8 m/s2 and π=22/7)

JEE Main 2023 (Online) 24th January Evening Shift

Answer Key & Explanation

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1. Ans. Correct answer is 1150

Explanation

We can use the Young-Laplace equation to find the difference in pressure inside and outside the air bubble due to surface tension:

$$\Delta P = 2\frac{T}{R}$$

where ΔP is the pressure difference, T is the surface tension, and R is the radius of the bubble.

Plugging in the given values:

$$\Delta P = 2\frac{0.075\,\mathrm{Nm}^{-1}}{1.0\,\mathrm{mm}} = 2\frac{0.075\,\mathrm{Nm}^{-1}}{10^{-3}\,\mathrm{m}} = 150\,\mathrm{Pa}$$

Now, we need to account for the hydrostatic pressure due to the depth of the bubble below the free surface:

$$P_{hydrostatic} = \rho g h$$

where p is the density of the liquid, g is the acceleration due to gravity, and h is the depth below the free surface.

Plugging in the given values:

$$P_{hydrostatic} = 1000\,\mathrm{kg\,m}^{-3} \cdot 10\,\mathrm{ms}^{-2} \cdot 0.1\,\mathrm{m} = 1000\,\mathrm{Pa}$$

So, the total pressure difference inside the bubble compared to atmospheric pressure is the sum of the pressure difference due to surface tension and hydrostatic pressure:

$$\Delta P_{total} = \Delta P + P_{hydrostatic} = 150\,\mathrm{Pa} + 1000\,\mathrm{Pa} = 1150\,\mathrm{Pa}$$

2. Ans. Correct answer is 40

Explanation

Given, energy per unit volume = $\frac{1}{2} \times$ stress $\times$ strain

The stress can be given as stress $= Y \times$ strain, where Y is the Young's modulus.

The energy stored in the wire can be written as:

Energy $= \frac{1}{2} \times$ stress $\times$ strain $\times$ volume

Substituting the stress formula, we get:

Energy $= \frac{1}{2} \times Y \times \text{strain}^2 \times A \times L$

We are given that the energy stored is 80 J, the original length of the wire is 20 m, the elongation is 2 cm, and the Young's modulus is $2.0 \times 10^{11}\,\text{Nm}^{-2}$. We need to find the cross-sectional area (A) of the wire.

$$80 = \frac{1}{2} \times 2 \times 10^{11} \times \left(\frac{2\times10^{-2}}{20}\right)^2 \times A \times 20$$

Now we can solve for A:

$$A = \frac{80\times20^2}{(2.0\times10^{11})\times(2\times10^{-2})^2} = 40 \times 10^{-6}\,\text{m}^2$$

To convert the area to mm^2, we multiply by 10^6:

$$A = 40 \times 10^{-6} \times 10^6 = 40\,\text{mm}^2$$

So, the cross-sectional area of the wire is $40\,\text{mm}^2$.

3. Ans. Correct answer is 4

Explanation

We can use the Bernoulli equation and continuity equation to solve this problem. The Bernoulli equation is given by:

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

The continuity equation is given by:

$$A_1 v_1 = A_2 v_2$$

From the given data, we have:

$$P_1 - P_2 = 3\,\mathrm{Nm}^{-2}\ A_1 = 10\,\mathrm{cm}^2 = 10 \times 10^{-4}\,\mathrm{m}^2\ A_2 = 5\,\mathrm{cm}^2 = 5 \times 10^{-4}\,\mathrm{m}^2$$
$$\rho = 1.25 \times 10^3\,\mathrm{kg\,m}^{-3}$$

Rearrange the continuity equation to solve for v_2:

$$v_2 = \frac{A_1}{A_2} v_1 = 2v_1$$

Substitute v_2 and rearrange the Bernoulli equation:

$$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2)$$

$$3 = \frac{1}{2} \times 1.25 \times 10^3(4v_1^2 - v_1^2)$$

Now, solve for v_1:

$$3 = \frac{1}{2} \times 1.25 \times 10^3 \times 3v_1^2\ v_1^2 = \frac{3}{1.875 \times 10^3}$$

$$v_1 = \sqrt{\frac{3}{1.875 \times 10^3}}$$

$$v_1 \approx 0.0400\,\mathrm{m\,s}^{-1}$$

Now, calculate the rate of flow of glycerin through the pipe (volume flow rate) using v_1 and A_1:

$$Q = A_1 v_1$$

$$Q = 10 \times 10^{-4} \times 0.0400$$

$$Q = 4 \times 10^{-5}\,\mathrm{m}^3\,\mathrm{s}^{-1}$$

So, the rate of flow of glycerin through the pipe is $4 \times 10^{-5}\,\mathrm{m}^3\,\mathrm{s}^{-1}$, and the value of x is 4.

4. Ans. Correct answer is 264

Explanation

To calculate the work done to increase the radius of a soap bubble, we can use the formula:

$$W = T\Delta A$$

where W is the work done, T is the surface tension, and ΔA is the change in surface area.

For a soap bubble, we need to consider both the inner and outer surfaces, so the surface area is doubled. The surface area of a sphere is:

$$A = 4\pi r^2$$

The initial surface area of the soap bubble is:

$$A_1 = 2 \cdot 4\pi(0.1\,\mathrm{m})^2 = 8\pi(0.1\,\mathrm{m})^2$$

The final surface area of the soap bubble is:

$$A_2 = 2 \cdot 4\pi(0.2\,\mathrm{m})^2 = 8\pi(0.2\,\mathrm{m})^2$$

The change in surface area is:

$$\Delta A = A_2 - A_1 = 8\pi(0.2\,\mathrm{m})^2 - 8\pi(0.1\,\mathrm{m})^2$$

Now, we can calculate the work done:

$$W = T\Delta A = (3.5 \times 10^{-2}\,\mathrm{Nm}^{-1})[8\pi(0.2\,\mathrm{m})^2 - 8\pi(0.1\,\mathrm{m})^2]$$

Using the given value of π:

$$W = (3.5 \times 10^{-2}\,\mathrm{Nm}^{-1})[8(22/7)(0.2\,\mathrm{m})^2 - 8(22/7)(0.1\,\mathrm{m})^2]$$

$$W = (3.5 \times 10^{-2}\,\mathrm{Nm}^{-1})[8(22/7)(0.04\,\mathrm{m}^2) - 8(22/7)(0.01\,\mathrm{m}^2)]$$

$$W = (3.5 \times 10^{-2}\,\mathrm{Nm}^{-1})[8(22/7)(0.03\,\mathrm{m}^2)]$$

$$W = 2 \times 1.32 \times 10^{-2}$$

$$W = 2 \times 1.32 \times 10^{-2}$$

$$W = 2 \times 132 \times 10^{-4}\,\mathrm{J}$$

$$W = 264 \times 10^{-4}\,\mathrm{J}$$

The work done to increase the radius of the soap bubble is 264×10^{-4} J.

5. Ans. Correct answer is 80

Explanation

To determine the fundamental frequency of the vibrating wire, we need to first find the tension (T) in the wire and the wave velocity (V) in the wire.

Tension in the wire (T): We used Young's modulus (Y) to relate the stress and strain in the wire. The formula for stress is:

$$\text{stress} = Y \times \text{strain}$$

Here, the strain is the extension (ΔL) divided by the original length (L):

$$\text{strain} = \frac{\Delta L}{L}$$

Now, the tension (T) in the wire is the product of stress and cross-sectional area (A):

$$T = \text{stress} \times A$$

Combining the above equations, we get the expression for tension:

$$T = \frac{Y \Delta L}{L} \times A$$

Wave velocity in the wire (V): The linear mass density (μ) of the wire is given by:

$\mu = \frac{m}{L}$

We need to find the ratio $\frac{T}{\mu}$, which represents the square of the wave velocity. Using the expressions for tension and linear mass density, we get:

$$\frac{T}{\mu} = \frac{Y\Delta L}{L} \times \frac{A}{m} = \frac{Y\Delta L}{L} \times \frac{1}{\rho}$$

Here, ρ is the density of the wire material. Plugging in the given values, we find the value of $\frac{T}{\mu}$, which is:

$$\frac{T}{\mu} = 6.4 \times 10^3$$

Now, we find the wave velocity (V) by taking the square root of $\frac{T}{\mu}$:

$$V = \sqrt{T/\mu} = 80\,\mathrm{m/s}$$

Fundamental frequency (f): Finally, we find the fundamental frequency of the vibrating wire using the formula:

$$f = \frac{V}{2L}$$

Plugging in the values, we get the fundamental frequency (f) as:

$$f = 80\,\mathrm{Hz}$$

So, the fundamental frequency of vibration in the wire is 80 Hz.

6. Ans. Correct answer is 2

Explanation

Given:

When tension $T_1 = 100\,\mathrm{N}$, extension $= l_1 - l_0$.
When tension $T_2 = 120\,\mathrm{N}$, extension $= l_2 - l_0$.

Now, let's write the equations using Hooke's Law:

$$100 = k(l_1 - l_0)$$

$$120 = k(l_2 - l_0)$$

Divide the first equation by the second equation:

$$\frac{5}{6} = \frac{l_1 - l_0}{l_2 - l_0}$$

Given the relationship between l_1 and l_2:

$$10l_2 = 11l_1$$

Now, let's solve for l_0:

$$5l_2 - 5l_0 = 6l_1 - 6l_0$$

$$l_0 = 6l_1 - 5l_2$$

Substitute the relationship between l_1 and l_2:

$$l_0 = 6l_1 - 5\left(\frac{11l_1}{10}\right)$$

$$l_0 = 6l_1 - \frac{11l_1}{2}$$

$$l_0 = \frac{l_1}{2}$$

Therefore, the natural length of the wire is $\frac{1}{x}l_1 = \frac{2}{1}l_1 = 2l_1$.

The value of x is 2.

7. Ans. Correct answer is 80

Explanation

By equation of continuity

$$A_1 V_1 = A_2 V_2$$

$$V_2 = \frac{2 \times 4}{10 \times 10^{-2}} = 80\,\mathrm{cm/s}$$

8. Ans. Correct answer is 20

9. Ans. Correct answer is 4

Explanation

The change in length of the rod when it is heated is given by the equation:

$$\Delta L = L_0 \cdot \alpha \cdot \Delta T$$

where

ΔL is the change in length,
L_0 is the original length,
α is the coefficient of linear expansion, and
ΔT is the change in temperature.

Substituting the given values:

$$\Delta L = 1\,\mathrm{m} \cdot 10^{-5}\,\mathrm{K}^{-1} \cdot 200\,\mathrm{K} = 0.002\,\mathrm{m}$$

The rod is not allowed to extend or bend, so a stress is created in the rod. This stress can be calculated using Young's modulus (Y), which is the ratio of the stress (force per unit area, F/A) to the strain (change in length per unit length, $\Delta L / L_0$):

$$Y = \frac{F/A}{\Delta L / L_0}$$

Rearranging for F gives:

$$F = Y \cdot A \cdot \frac{\Delta L}{L_0}$$

Substituting the given values:

$$F = 2 \times 10^{11}\,\mathrm{N/m}^2 \cdot 10^{-4}\,\mathrm{m}^2 \cdot \frac{0.002\,\mathrm{m}}{1\,\mathrm{m}} = 4 \times 10^4\,\mathrm{N}$$

So the compressive tension produced in the rod is 4×10^4 N.

10. Ans. Correct answer is 10

Explanation

The terminal velocity of a small spherical object moving under the action of gravity through a fluid medium is given by Stokes' Law, which is stated as:

$$v = \frac{2}{9}\frac{r^2 g(\rho_p - \rho_f)}{\eta},$$

where:

v is the velocity of the object (in this case, the air bubble),
r is the radius of the object,
g is the acceleration due to gravity,
ρ_p is the density of the object (negligible in this case, as it's an air bubble),
ρ_f is the density of the fluid (the solution), and
η is the coefficient of viscosity of the fluid.

Since we are neglecting the density of the air bubble, the formula simplifies to:

$$v = \frac{2}{9}\frac{r^2 g \rho_f}{\eta}.$$

Rearranging for η, we get:

$$\eta = \frac{2}{9}\frac{r^2 g \rho_f}{v}.$$

Given that $r = \frac{6\text{ mm}}{2} = 3\text{ mm} = 3 \times 10^{-3}\text{ m}$, $g = 10\text{ ms}^{-2}$, $\rho_f = 1750\text{ kg/m}^3$, and $v = 0.35\text{ cm/s} = 0.35 \times 10^{-2}\text{ m/s}$, we can substitute these values into the formula to find η:

$$\eta = \frac{2}{9}\frac{(3\times10^{-3})^2\times10\times1750}{0.35\times10^{-2}} = 10\text{ Pas}.$$

Therefore, the coefficient of viscosity of the solution is 10 Pas.

11. Ans. Correct answer is 11

Explanation

To find the mass m of the metal block, we need to consider the tensile stress developed in the wire. The formula for tensile stress is:

Tensile Stress $= \frac{\text{Force}}{\text{Area}}$

The force acting on the wire is the weight of the metal block, which can be represented as $F = mg$.

The cross-sectional area of the wire, given its diameter $d = 14\,mm$, can be calculated using the formula for the area of a circle:

$$A = \pi(\frac{d}{2})^2 = \pi(\frac{14}{2})^2\,mm^2$$

Now, convert the area to m^2:

$$A = \pi(\frac{14\times10^{-3}}{2})^2\,m^2$$

We are given that the tensile stress developed in the wire is $7 \times 10^5\,Nm^{-2}$. Using the tensile stress formula, we can write:

$$7 \times 10^5\,Nm^{-2} = \frac{mg}{A}$$

Now, solve for the mass m:

$$m = \frac{7\times10^5\,Nm^{-2}\cdot A}{g}$$

Substitute the values of A and g into the equation:

$$m = \frac{7\times10^5\,Nm^{-2}\cdot\pi(\frac{14\times10^{-3}}{2})^2\,m^2}{9.8\,ms^{-2}}$$

After calculating, we get:

$$m \approx 11\,kg$$

Therefore, the mass of the metal block is approximately $11\,kg$.

12. Ans. Correct answer is 25

Explanation

$$\text{Strain } = \frac{\text{stress}}{Y} = \frac{\frac{62.8 \times 10^3}{\pi \times (0.02)^2}}{2 \times 10^{11}}$$

$$= \frac{62.8 \times 10^3}{3.14 \times 4 \times 10^{-4} \times 2 \times 10^{11}}$$

$$= 2.5 \times 10^{-4}$$

$$= 25 \times 10^{-5}$$

13. Ans. Correct answer is 2

Explanation

$$\mathrm{AV} = \mathrm{av}$$

$$750 \times 10^{-4} \times \left(\frac{dh}{dt}\right) = \left(500 \times 10^{-6}\right)\left(30 \times 10^{-2}\right)$$

$$\frac{dh}{dt} = \frac{15 \times 10^{-5}}{75 \times 10^{-3}}$$

$$= \frac{1}{5} \times 10^{-2}$$

$$= 2 \times 10^{-3}\ \mathrm{m/s}$$

$$\therefore x = 2$$

14. Ans. Correct answer is 1

Explanation

Given, Volume of water, $V_1 = 1$ litre

Volume of liquid, $V_2 = 2$ litre,

Pressure $= P$

$$\left(\frac{\Delta V}{V} \times 100\right)_{\text{water}} = 0.01\%;$$

$$\left(\frac{\Delta V}{V} \times 100\right)_{\text{liquid}} = 0.03\%$$

Bulk modulus, $B = \dfrac{-PV}{\Delta V}$;

$$\frac{B_{\text{water}}}{B_{\text{liquid}}} = \frac{\left(\frac{\Delta V}{V}\right)_{\text{liquid}}}{\left(\frac{\Delta V}{V}\right)_{\text{water}}} = \frac{\frac{0.03}{100}}{\frac{0.01}{100}} = 3$$

On comparing the given value with $\frac{3}{x}$, we get $x = 1$.

15. Ans. Correct answer is 60

Explanation

When the rod is cooled from 210°C to 160°C, it will contract in length due to thermal contraction. The change in length of the rod is given by:

$\Delta L = L\alpha\Delta T$

where L is the original length of the rod, α is the coefficient of linear expansion, and ΔT is the change in temperature.

When a mass M is attached to the lower end of the rod, it will stretch due to the weight of the mass. The elongation of the rod is given by:

$$\Delta L = \frac{MgL}{AY}$$

where M is the mass, g is the acceleration due to gravity, A is the cross-sectional area of the rod, Y is the Young's modulus of the rod, and L is the original length of the rod.

$$\therefore L\alpha\Delta T = \frac{MgL}{AY}$$

$$\Rightarrow \alpha\Delta T = \frac{Mg}{AY}$$

$$\Rightarrow Mg = AY\alpha\Delta T$$

$$\Rightarrow \mathrm{M} \times 10 = 2 \times 10^{11} \times 3 \times 10^{-6} \times 2 \times 10^{-5} \times 50$$

$$\Rightarrow \mathrm{M} = 60\,\mathrm{kg}$$

16. Ans. Correct answer is 25

Explanation

As the block moves with constant speed, the horizontal force is balanced by viscous force thus

$$F = \eta A \frac{\Delta v}{\Delta z}$$

$$0.1 = 5 \times 10^{-3} \times 0.2 \times \frac{v}{.25 \times 10^{-3}}$$

$$\Rightarrow v = 25 \times 10^{-3} \text{ m/s}$$

17. Ans. Correct answer is 1

Explanation

Surface Tension $= \mathrm{T}$

R : Radius of bigger drop

r : Radius of smaller drop

Volume will remain same

$\frac{4}{3}\pi R^3 = 1000 \times \frac{4}{3}\pi r^3$

$\mathrm{R} = 10\mathrm{r}$

$\mathrm{u_i} = \mathrm{T} \cdot 4\pi\mathrm{R}^2$

$\mathrm{u_f} = \mathrm{T}.4\pi\mathrm{r}^2 \times 1000$

$\frac{\mathrm{u_f}}{\mathrm{u_i}} = \frac{1000\mathrm{r}^2}{\mathrm{R}^2}$

$\frac{\mathrm{u_f}}{\mathrm{u_i}} = \frac{10}{1}$

So, $x = 1$

18. Ans. Correct answer is 5

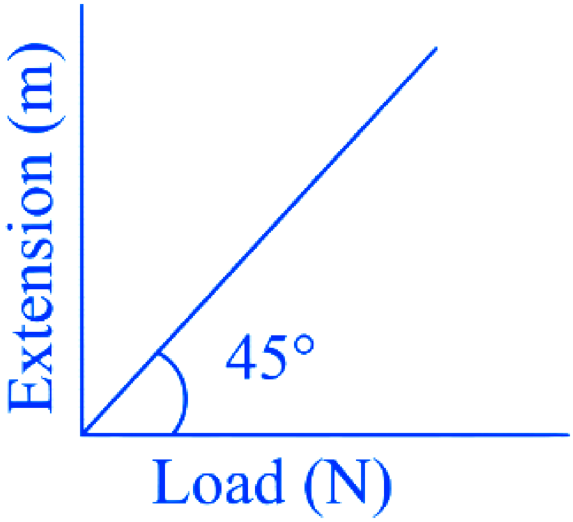
Explanation

Given, Length, $L = 62.8\,\mathrm{cm}$

diameter, $d = 4\,\mathrm{mm}$

radius, $r = 2\,\mathrm{mm}$

$y = x \times 10^4\,\mathrm{N/m^2}$



According to graph, $\Delta l / f = \tan 45^\circ = 1$

$Y = \frac{FL}{A \cdot \Delta L}$

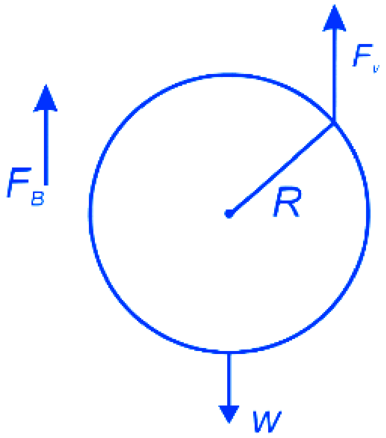
$Y = \frac{1 \times 62.8 \times 10^{-2}}{3.14 \times 2 \times 2 \times 10^{-6}} = 5 \times 10^4\,\mathrm{N/m^2}$

$\therefore$ x = 5

19. Ans. Correct answer is 7

Explanation

At state of terminal speed, net force on the ball is zero



$$\therefore \quad F_v = w - F_B$$

$$= \left(\frac{4}{3}\pi R^3 \rho_b g\right) - \left(\frac{4}{3}\pi R^3 \rho_l g\right)$$

$$= \frac{4}{3}\pi R^3 \left(\rho_b - \rho_l\right) g$$

$$= \frac{4}{3} \times \frac{22}{7} \times \left(10^{-3}\right)^3 \left[9 \times 10^3\right] \times 9.8$$

$$= 3696 \times 10^{-7}$$

$$\therefore x = 7$$

MCQ (Single Correct Answer)

Q.1. A wire of length ' L ' and radius ' r ' is clamped rigidly at one end. When the other end of the wire is pulled by a force f, its length increases by ' l '. Another wire of same material of length ' 2 L ' and radius ' 2L ' is pulled by a force ' 2r '. Then the increase in its length will be:

A $2l$

B $4l$

C l

D $l/2$

JEE Main 2023 (Online) 15th April Morning Shift

Q.2. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R

Assertion A: A spherical body of radius (5±0.1) mm having a particular density is falling through a liquid of constant density. The percentage error in the calculation of its terminal velocity is 4%.

Reason R: The terminal velocity of the spherical body falling through the liquid is inversely proportional to its radius.

In the light of the above statements, choose the correct answer from the options given below

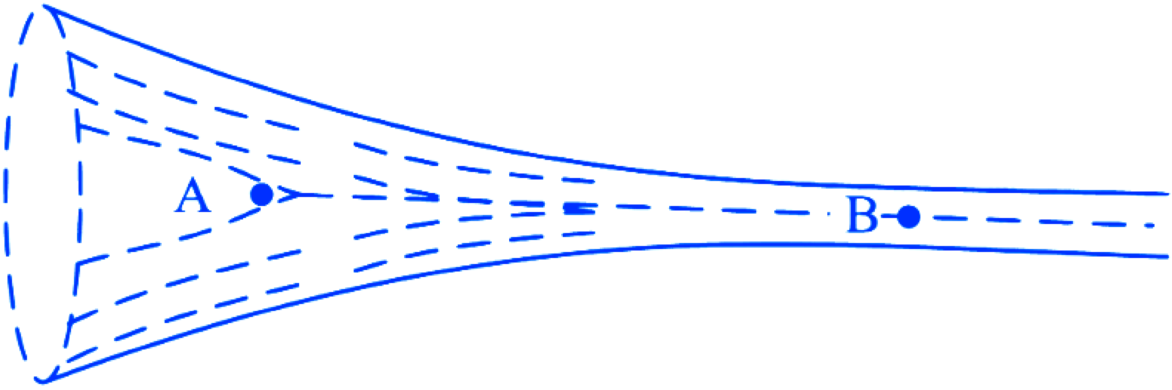
Ⓐ A is false but $\mathbf{R}$ is true

Ⓑ A is true but $\mathbf{R}$ is false

Ⓒ Both $\mathbf{A}$ and $\mathbf{R}$ are true but $\mathbf{R}$ is NOT the correct explanation of $\mathbf{A}$

Ⓓ Both $\mathbf{A}$ and $\mathbf{R}$ are true and $\mathbf{R}$ is the correct explanation of $\mathbf{A}$

Q.3.



The figure shows a liquid of given density flowing steadily in horizontal tube of varying cross - section. Cross sectional areas at A is 1.5 cm2, and B is 25 mm2, if the speed of liquid at B is 60 cm/s then (PA−PB) is :

(Given PA and PB are liquid pressures at A and B% points.

density p=1000 kg m^{-3}

A and B are on the axis of tube

A $27\,\mathrm{Pa}$

B $175\,\mathrm{Pa}$

C $135\,\mathrm{Pa}$

D $36\,\mathrm{Pa}$

JEE Main 2023 (Online) 13th April Morning Shift

Q.4. Under isothermal condition, the pressure of a gas is given by P=a V^{-3}, where a is a constant and V is the volume of the gas. The bulk modulus at constant temperature is equal to

A $\frac{P}{2}$

B 2 P

C 3 P

D P

JEE Main 2023 (Online) 13th April Morning Shift

Q.5. Eight equal drops of water are falling through air with a steady speed of 10 cm/s. If the drops coalesce, the new velocity is: -

- A $40 \mathrm{~cm} / \mathrm{s}$
- B $16 \mathrm{~cm} / \mathrm{s}$
- C $10 \mathrm{~cm} / \mathrm{s}$
- D $5 \mathrm{~cm} / \mathrm{s}$

JEE Main 2023 (Online) 11th April Evening Shift

Q.6. Young's moduli of the material of wires A and B are in the ratio of 1:4, while its area of cross sections are in the ratio of 1:3. If the same amount of load is applied to both the wires, the amount of elongation produced in the wires A and B will be in the ratio of

[Assume length of wires A and B are same]

- A 1 : 12
- B 1 : 36

Ⓒ 12 : 1

Ⓓ 36 : 1

JEE Main 2023 (Online) 10th April Evening Shift

Q.7. Given below are two statements:

Statement I: Pressure in a reservoir of water is same at all points at the same level of water.

Statement II: The pressure applied to enclosed water is transmitted in all directions equally.

In the light of the above statements, choose the correct answer from the options given below:

Ⓐ Both Statement I and Statement II are false

Ⓑ Statement I is false but Statement II is true

Ⓒ Statement I is true but Statement II is false

Ⓓ Both Statement I and Statement II are true

JEE Main 2023 (Online) 10th April Morning Shift

Q.8. A hydraulic automobile lift is designed to lift vehicles of mass 5000 kg. The area of cross section of the cylinder carrying the load is 250 cm2. The maximum pressure the smaller piston would have to bear is (Assume g=10m/s^2)

A $20 \times 10^{+6}$ Pa

B $200 \times 10^{+6}$ Pa

C $2 \times 10^{+5}$ Pa

D $2 \times 10^{+6}$ Pa

JEE Main 2023 (Online) 8th April Evening Shift

Q.9. An air bubble of volume 1 cm3 rises from the bottom of a lake 40 m deep to the surface at a temperature of 12∘C. The atmospheric pressure is 1×105 Pa the density of water is 1000 kg/m3 and g=10 m/s2. There is no difference of the temperature of water at the depth of 40 m and on the surface. The volume of air bubble when it reaches the surface will be:

A $4 \mathrm{~cm}^3$

B $3 \mathrm{~cm}^3$

C $2 \mathrm{~cm}^3$

D $5 \mathrm{~cm}^3$

JEE Main 2023 (Online) 8th April Morning Shift

Q.10. An aluminium rod with Young's modulus Y=7.0×1010 N/m2 undergoes elastic strain of 0.04%. The energy per unit volume stored in the rod in SI unit is:

Ⓐ 5600

Ⓑ 2800

Ⓒ 11200

Ⓓ 8400

JEE Main 2023 (Online) 8th April Morning Shift

Q.11. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R

Assertion A: When you squeeze one end of a tube to get toothpaste out from the other end, Pascal's principle is observed.

Reason R: A change in the pressure applied to an enclosed incompressible fluid is transmitted undiminished to every portion of the fluid and to the walls of its container.

In the light of the above statements, choose the most appropriate answer
from the options given below

Ⓐ Both A and R are correct but R is NOT the correct explanation of A

Ⓑ A is not correct but R is correct

Ⓒ A is correct but R is not correct

Ⓓ Both A and B are correct and R is the correct explanation of A

JEE Main 2023 (Online) 6th April Evening Shift

Q.12. A small ball of mass M and density p is dropped in a viscous liquid of density p0. After some time, the ball falls with a constant velocity. What is the viscous force on the ball?

Ⓐ $\mathrm{F} = \mathrm{Mg}\left(1 - \frac{\rho_{\mathrm{O}}}{\rho}\right)$

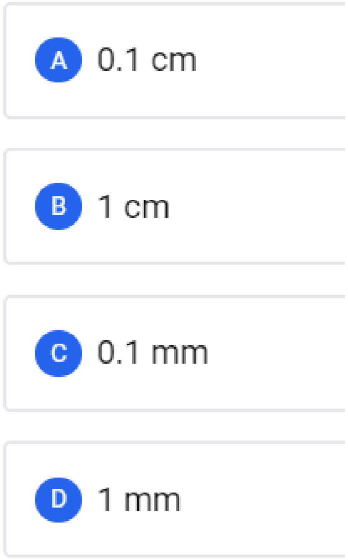
Ⓑ $\mathrm{F} = \mathrm{Mg}\left(1 + \frac{\rho}{P_o}\right)$

Ⓒ $\mathrm{F} = \mathrm{Mg}\left(1 + \frac{\rho_{\mathrm{o}}}{\rho}\right)$

Ⓓ $F = Mg\,(1 \pm \rho\rho_0)$

JEE Main 2023 (Online) 6th April Morning Shift

Q.13. The Young's modulus of a steel wire of length 6 m and cross-sectional area 3 mm2, is 2×1011 N/m2. The wire is suspended from its support on a given planet. A block of mass 4 kg is attached to the free end of the wire. The acceleration due to gravity on the planet is 14 of its value on the earth. The elongation of wire is (Take g on the earth =10 m/s2):



Ⓐ 0.1 cm

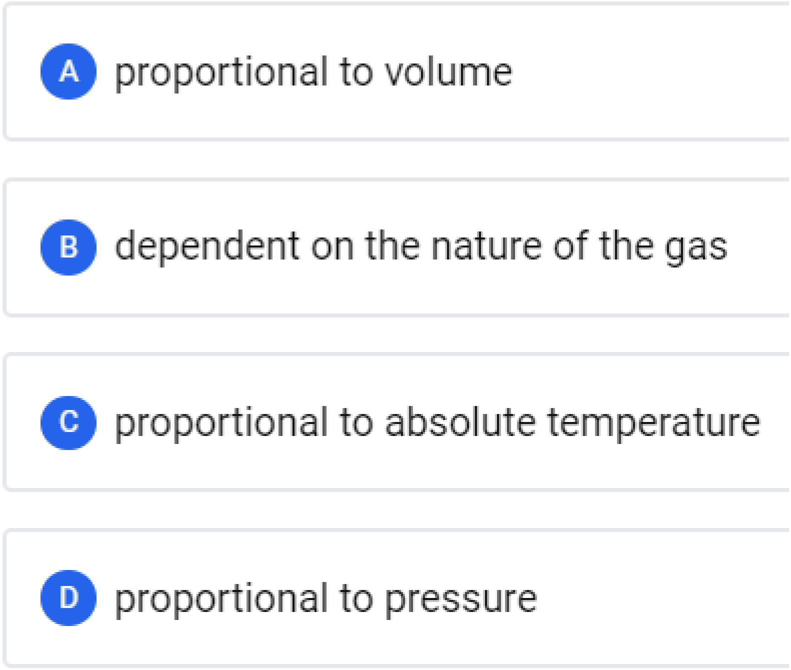
Ⓑ 1 cm

Ⓒ 0.1 mm

Ⓓ 1 mm

JEE Main 2023 (Online) 1st February Evening Shift

Q.14. The average kinetic energy of a molecule of the gas is



Ⓐ proportional to volume

Ⓑ dependent on the nature of the gas

Ⓒ proportional to absolute temperature

Ⓓ proportional to pressure

JEE Main 2023 (Online) 1st February Morning Shift

Q.15. A mercury drop of radius 10−3 m is broken into 125 equal size droplets. Surface tension of mercury is 0.45 Nm−1. The gain in surface energy is:

A 28×10^{-5} J

B 17.5×10^{-5} J

C 5×10^{-5} J

D 2.26×10^{-5} J

JEE Main 2023 (Online) 1st February Morning Shift

Q.16. For a solid rod, the Young's modulus of elasticity is 3.2×1011Nm−2 and density is 8×103 kg m−3. The velocity of longitudinal wave in the rod will be.

A $3.65 \times 10^{3}\,\mathrm{ms}^{-1}$

B $6.32 \times 10^{3}\,\mathrm{ms}^{-1}$

C $18.96 \times 10^{3}\,\mathrm{ms}^{-1}$

D $145.75 \times 10^{3}\,\mathrm{ms}^{-1}$

JEE Main 2023 (Online) 31st January Evening Shift

Q.17. Under the same load, wire A having length 5.0 m and cross section 2.5×10−5 m2 stretches uniformly by the same amount as another wire B of length 6.0 m and a cross section of 3.0×10−5 m2 stretches. The ratio of the Young's modulus of wire A to that of wire B will be:

Ⓐ $1:2$

Ⓑ $1:4$

Ⓒ $1:1$

Ⓓ $1:10$

JEE Main 2023 (Online) 31st January Evening Shift

Q.18. If 1000 droplets of water of surface tension 0.07 N/m, having same radius 1 mm each, combine to from a single drop. In the process the released surface energy is: -

$\left(\text{Take}\, \pi=\frac{22}{7}\right)$

Ⓐ $7.92 \times 10^{-4}\, \mathrm{J}$

Ⓑ $7.92 \times 10^{-6}\, \mathrm{J}$

C 8.8×10^{-5} J

D 9.68×10^{-4} J

JEE Main 2023 (Online) 31st January Morning Shift

Q.19. A force is applied to a steel wire 'A', rigidly clamped at one end. As a result, elongation in the wire is 0.2 mm. If same force is applied to another steel wire ' B ' of double the length and a diameter 2.4 times that of the wire ' A ', the elongation in the wire ' B ' will be (wires having uniform circular cross sections)

A 6.9×10^{-2} mm

B 6.06×10^{-2} mm

C 2.77×10^{-2} mm

D 3.0×10^{-2} mm

JEE Main 2023 (Online) 30th January Evening Shift

Q.20. The height of liquid column raised in a capillary tube of certain radius when dipped in liquid A vertically is, 5 cm. If the tube is dipped in a similar manner in another liquid B of surface tension and density double the values of liquid A, the height of liquid column raised in liquid B would be __________ m.

A 0.05

B 0.20

C 0.5

D 0.10

JEE Main 2023 (Online) 30th January Morning Shift

Q.21. Choose the correct relationship between Poisson ratio (σ), bulk modulus (K) and modulus of rigidity (η) of a given solid object:

A $\sigma=\frac{3K+2\eta}{6K+2\eta}$

B $\sigma=\frac{3K-2\eta}{6K+2\eta}$

C $\sigma=\frac{6K+2\eta}{3K-2\eta}$

D $\sigma=\frac{6K-2\eta}{3K-2\eta}$

JEE Main 2023 (Online) 30th January Morning Shift

Q.22. A fully loaded Boeing aircraft has a mass of 5.4×105 kg. Its total wing area is 500 m2. It is in level flight with a speed of 1080 km/h. If the density of air p is 1.2 kg m−3, the fractional increase in the speed of the air on the upper surface of the wing relative to the lower surface in percentage will be.
(g=10 m/s2)

A 16

B 8

C 6

D 10

JEE Main 2023 (Online) 29th January Evening Shift

Q.23. Surface tension of a soap bubble is 2.0×10−2Nm−1. Work done to increase the radius of soap bubble
from 3.5 cm to 7 cm will be:

Take $\left[\pi=\frac{22}{7}\right]$

A $18.48 \times 10^{-4}\,\mathrm{J}$

B $5.76 \times 10^{-4}\,\mathrm{J}$

C $0.72 \times 10^{-4}\,\mathrm{J}$

D $9.24 \times 10^{-4}\,\mathrm{J}$

JEE Main 2023 (Online) 29th January Morning Shift

Q.24. A bicycle tyre is filled with air having pressure of 270 kPa at 27∘C. The approximate pressure of the air in the tyre when the temperature increases to 36∘C is

A 262 kPa

B 360 kPa

C 270 kPa

D 278 kPa

JEE Main 2023 (Online) 29th January Morning Shift

Q.25. Match List I with List II

	List I		List II
A.	Surface tension	I.	kg m−1 s−1
B.	Pressure	II.	kg ms−1

	List I		List II
C.	Viscosity	III.	kg m−1 s−2
D.	Impulse	IV.	kg s−2

Choose the correct answer from the options given below :

Ⓐ A-IV, B-III, C-I, D-II

Ⓑ A-IV, B-III, C-II, D-I

Ⓒ A-I, B-I, C-III, D-IV

Ⓓ A-III, B-IV, C-I, D-II

JEE Main 2023 (Online) 29th January Morning Shift

Q.26. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R

Assertion A : Steel is used in the construction of buildings and bridges.

Reason R : Steel is more elastic and its elastic limit is high.

In the light of above statements, choose the most appropriate answer from the options given below

A Both A and R are correct and R is the correct explanation of A

B A is correct but R is not correct

C Both A and R are correct but R is NOT the correct explanation of A

D A is not correct but R is correct

JEE Main 2023 (Online) 24th January Evening Shift

Q.27. The frequency (v) of an oscillating liquid drop may depend upon radius (r) of the drop, density (p) of liquid and the surface tension (s) of the liquid as $\nu = r^a \rho^b s^c$. The values of a, b and c respectively are

A $\left(\frac{3}{2}, \frac{1}{2}, -\frac{1}{2}\right)$

B $\left(-\frac{3}{2}, -\frac{1}{2}, \frac{1}{2}\right)$

C $\left(\frac{3}{2}, -\frac{1}{2}, \frac{1}{2}\right)$

D $\left(-\frac{3}{2}, \frac{1}{2}, \frac{1}{2}\right)$

JEE Main 2023 (Online) 24th January Evening Shift

Q.28. A 100 m long wire having cross-sectional area 6.25×10−4 m2 and Young's modulus is 1010 Nm−2 is subjected to a load of 250 N, then the elongation in the wire will be :

A $6.25 \times 10^{-6}\,\mathrm{m}$

B $4 \times 10^{-3}\,\mathrm{m}$

C $4 \times 10^{-4}\,\mathrm{m}$

D $6.25 \times 10^{-3}\,\mathrm{m}$

JEE Main 2023 (Online) 24th January Morning Shift

Answer Key & Explanation

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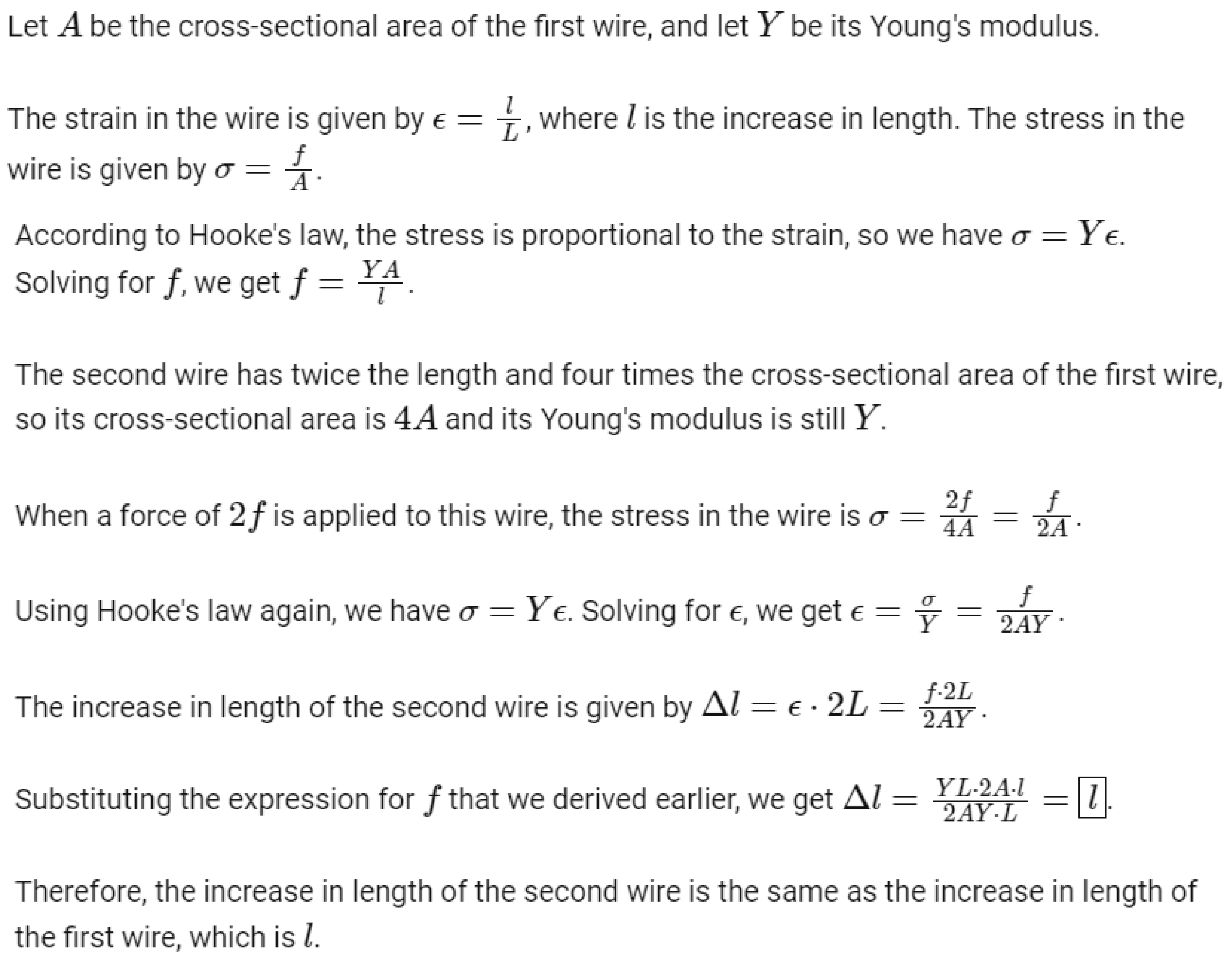
1. Ans. (C)

Explanation



Let A be the cross-sectional area of the first wire, and let Y be its Young's modulus.

The strain in the wire is given by $\epsilon = \frac{l}{L}$, where l is the increase in length. The stress in the wire is given by $\sigma = \frac{f}{A}$.

According to Hooke's law, the stress is proportional to the strain, so we have $\sigma = Y\epsilon$. Solving for f, we get $f = \frac{YA}{l}$.

The second wire has twice the length and four times the cross-sectional area of the first wire, so its cross-sectional area is $4A$ and its Young's modulus is still Y.

When a force of $2f$ is applied to this wire, the stress in the wire is $\sigma = \frac{2f}{4A} = \frac{f}{2A}$.

Using Hooke's law again, we have $\sigma = Y\epsilon$. Solving for ϵ, we get $\epsilon = \frac{\sigma}{Y} = \frac{f}{2AY}$.

The increase in length of the second wire is given by $\Delta l = \epsilon \cdot 2L = \frac{f \cdot 2L}{2AY}$.

Substituting the expression for f that we derived earlier, we get $\Delta l = \frac{YL \cdot 2A \cdot l}{2AY \cdot L} = \boxed{l}$.

Therefore, the increase in length of the second wire is the same as the increase in length of the first wire, which is l.

2. Ans. (B)

Explanation

The statement about the terminal velocity of a spherical body falling through a liquid being inversely proportional to its radius is true. This can be shown by applying the Stokes' law, which states that the drag force experienced by a spherical body moving through a viscous fluid is proportional to its velocity and radius. The terminal velocity is reached when the drag force equals the weight of the body, and this occurs when the force of gravity acting on the body is balanced by the buoyant force and the drag force.

The statement about the percentage error in the calculation of the terminal velocity of the spherical body falling through the liquid being 4% is also true, and can be inferred from the given data. However, this statement alone does not provide a clear explanation or reasoning for Assertion A.

Therefore, while Assertion A is true, Reason R is also true but it does not provide a valid explanation for Assertion A. The correct answer is:

Assertion A is true, but Reason R is false.

3. Ans. (B)

Explanation

From continuity theorem $\mathrm{A_1 V_1 = A_2 V_2}$

$$1.5 \times \mathrm{V_1} = 25 \times 10^{-2} \times 60$$

$$\mathrm{V_1} = \frac{25 \times 60 \times 10^{-2} \times 10}{1.5}$$

$$\mathrm{V_1} = 10\,\mathrm{cm/s}$$

By Bernoulli's theorem

$$P_1 + \frac{1}{2} \times 1000 \times (0.1)^2 = P_2 + \frac{1}{2} \times 1000 \times (0.6)^2$$

$$P_1 + 5 = P_2 + \frac{1}{2} \times 1000 \times 36 \times 10^{-2}$$

$$P_1 + 5 = P_2 + 180$$

$$P_1 - P_2 = 175\,\mathrm{Pa}$$

4. Ans. (C)

The bulk modulus (B) of a substance is defined as the ratio of the infinitesimal pressure increase (ΔP) to the relative decrease in volume ($\frac{-\Delta V}{V}$) at constant temperature:

$$B = -V\frac{\Delta P}{\Delta V}$$

To find the bulk modulus for the given pressure-volume relationship, we first need to find the differential change in pressure with respect to volume:

$$P = aV^{-3}$$

Differentiate P with respect to V:

$$\frac{dP}{dV} = -3aV^{-4}$$

Now we can use the definition of the bulk modulus:

$$B = -V\frac{\Delta P}{\Delta V} = -V\frac{dP}{dV}$$

Plug in the value for $\frac{dP}{dV}$:

$$B = -V(-3aV^{-4})$$

Simplify the expression:

$$B = 3aV^{-3}$$

Notice that $3aV^{-3}$ is equal to $3P$, since $P = aV^{-3}$:

$$B = 3P$$

Therefore, the bulk modulus at constant temperature is equal to 3P.

5. Ans. (A)

Explanation

In this problem, we need to consider the terminal velocity of the droplets, which is reached when the gravitational force is balanced by the drag force acting on the droplet. Terminal velocity is related to the square of the droplet's radius.

The relationship between the terminal velocity (v) and the radius (r) of the droplet is given by:

$$v \propto r^2$$

Initially, there are 8 equal drops of water, each with radius r and velocity 10 cm/s. When these droplets coalesce, they form a single droplet with a larger radius R. The volume of the new droplet should be equal to the total volume of the 8 smaller droplets.

Using the volume formula for spheres, we can write the relationship between the radii as:

$$8 \cdot \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

Solving for R, we get:

$$R = 2r$$

Now, we can use the relationship between the terminal velocities and radii of the droplets:

$$\frac{v_1}{v_2} = \left(\frac{r}{R}\right)^2$$

Given the initial terminal velocity of 10 cm/s for the smaller droplets (v1) and the relationship between r and R:

$$\frac{10}{v_2} = \left(\frac{1}{2}\right)^2$$

Solving for the new terminal velocity (v2):

$$v_2 = 40 \text{ cm/s}$$

The new terminal velocity after the droplets coalesce is 40 cm/s.

6. Ans.(C)

Explanation

Given the formula for elongation in a material due to a force:

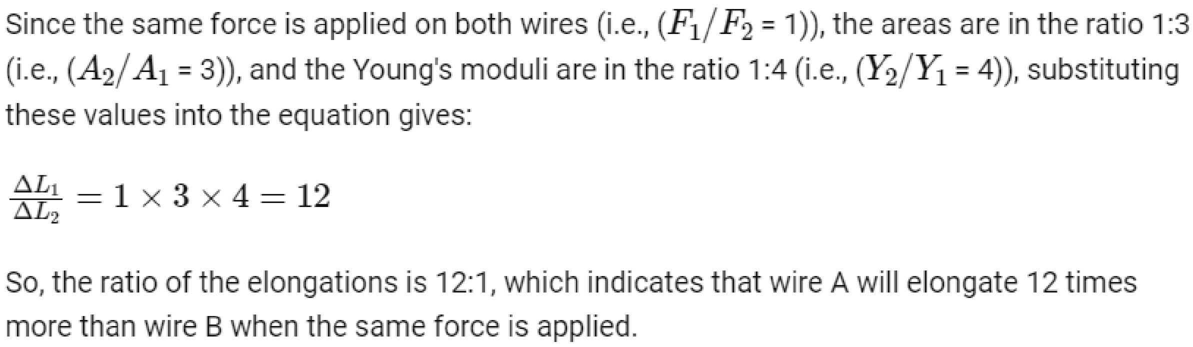
$$\Delta L = \frac{FL}{AY}$$

where:

F is the force applied,
L is the original length,
A is the cross-sectional area of the material, and
Y is Young's modulus of the material.

The ratio of the elongations in the two wires A and B is given by:

$$\frac{\Delta L_1}{\Delta L_2} = \frac{F_1}{F_2} \times \frac{A_2}{A_1} \times \frac{Y_2}{Y_1}$$



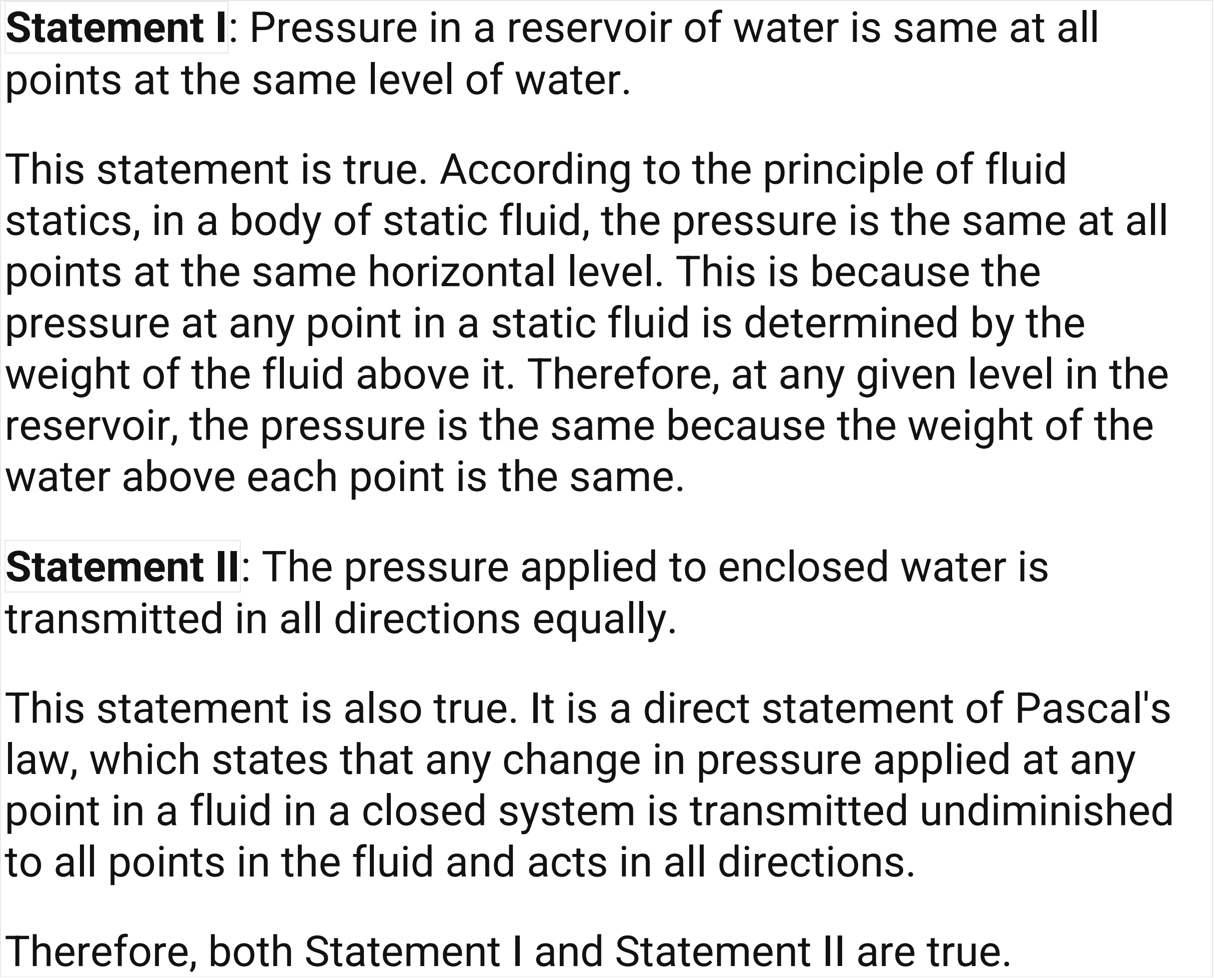
Since the same force is applied on both wires (i.e., (F_1/F_2 = 1)), the areas are in the ratio 1:3 (i.e., (A_2/A_1 = 3)), and the Young's moduli are in the ratio 1:4 (i.e., (Y_2/Y_1 = 4)), substituting these values into the equation gives:

$$\frac{\Delta L_1}{\Delta L_2} = 1 \times 3 \times 4 = 12$$

So, the ratio of the elongations is 12:1, which indicates that wire A will elongate 12 times more than wire B when the same force is applied.

7. Ans. (D)

Explanation



Statement I: Pressure in a reservoir of water is same at all points at the same level of water.

This statement is true. According to the principle of fluid statics, in a body of static fluid, the pressure is the same at all points at the same horizontal level. This is because the pressure at any point in a static fluid is determined by the weight of the fluid above it. Therefore, at any given level in the reservoir, the pressure is the same because the weight of the water above each point is the same.

Statement II: The pressure applied to enclosed water is transmitted in all directions equally.

This statement is also true. It is a direct statement of Pascal's law, which states that any change in pressure applied at any point in a fluid in a closed system is transmitted undiminished to all points in the fluid and acts in all directions.

Therefore, both Statement I and Statement II are true.

8. Ans. (D)

Explanation

A hydraulic lift works based on Pascal's principle, which states that the pressure applied at one point in an incompressible fluid is transmitted equally in all directions.

The force exerted by the car on the hydraulic fluid is equal to the weight of the car, which is $F = mg$, where m is the mass of the car and g is the acceleration due to gravity.

Substituting the given values, we get:

$$F = 5000\,\text{kg} \times 10\,\text{m/s}^2 = 50000\,\text{N}$$

The pressure exerted by the car on the hydraulic fluid is equal to the force divided by the area over which the force is distributed, which is $P = \frac{F}{A}$, where A is the cross-sectional area of the cylinder carrying the load.

However, the given area is in cm², so we need to convert it to m². We know that 1 m² = 10,000 cm², so:

$$A = 250\,\text{cm}^2 \times \frac{1\,\text{m}^{\ 2}}{10000\,\text{cm}^{\ 2}} = 0.025\,\text{m}^2$$

Substituting the values of force and area into the formula for pressure, we get:

$$P = \frac{50000\,\text{N}}{0.025\,\text{m}^{\ 2}} = 2 \times 10^6\,\text{Pa}$$

9. Ans. (D)

Explanation

The volume of the air bubble changes due to the change in pressure as it rises from the bottom of the lake to the surface. We can use Boyle's Law to calculate the change in volume, which states that the product of pressure and volume is constant for a given mass of confined gas held at a constant temperature:

$$P_1V_1 = P_2V_2$$

where P_1 and V_1 are the pressure and volume at the bottom of the lake and P_2 and V_2 are the pressure and volume at the surface of the lake.

At the bottom of the lake, the pressure is the atmospheric pressure plus the pressure due to the water column above the bubble:

$P_1 = P_{\text{atm}} + \rho g h$

where ρ is the density of water, g is the acceleration due to gravity, and h is the height of the water column. Substituting the given values, we get:

$P_1 = 1 \times 10^5 \text{ Pa} + 1000 \text{ kg/m}^3 \times 10 \text{ m/s}^2 \times 40 \text{ m} = 5 \times 10^5 \text{ Pa}$

At the surface of the lake, the pressure is the atmospheric pressure:

$$P_2 = P_{\text{atm}} = 1 \times 10^5 \text{ Pa}$$

The initial volume of the bubble is:

$$V_1 = 1 \text{ cm}^3 = 1 \times 10^{-6} \text{ m}^3$$

Substituting these values into Boyle's Law and solving for V_2, we get:

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{5 \times 10^5 \text{ Pa} \times 1 \times 10^{-6} \text{ m}^3}{1 \times 10^5 \text{ Pa}} = 5 \times 10^{-6} \text{ m}^3 = 5 \text{ cm}^3$$

So, the volume of the air bubble when it reaches the surface is 5 cm³.

10. Ans. (A)

Explanation

The strain energy stored per unit volume in a material under stress can be calculated using the following formula:

$U = \frac{1}{2} \sigma \epsilon$

where σ is the stress and ϵ is the strain.

For an elastic material, stress is proportional to strain (Hooke's law), and the constant of proportionality is the Young's modulus (Y). So we can write:

$\sigma = Y \epsilon$

Substituting this into the energy density equation we get:

$U = \frac{1}{2} Y \epsilon^2$

The strain given in the problem is 0.04%, which needs to be converted to a decimal for use in this formula. Therefore, $\epsilon = 0.04/100 = 0.0004$.

Substituting the values into the equation gives:

$$U = \frac{1}{2} \times 7.0 \times 10^{10} N/m^2 \times (0.0004)^2 = 5600\, J/m^3$$

11. Ans. (D)

Explanation

Assertion A states that when you squeeze one end of a tube to get toothpaste out from the other end, Pascal's principle is observed. This is true because when you apply pressure on one end of the tube, the pressure is transmitted uniformly throughout the enclosed incompressible fluid (the toothpaste in this case) and eventually pushes the toothpaste out of the other end.

Reason R provides the definition of Pascal's principle: "A change in the pressure applied to an enclosed incompressible fluid is transmitted undiminished to every portion of the fluid and to the walls of its container." This principle is directly applicable to the situation described in Assertion A. When you squeeze the tube, you apply pressure on the toothpaste, and this pressure is transmitted uniformly to all parts of the toothpaste, causing it to be pushed out of the other end.

Therefore, Option D is the correct choice as both Assertion A and Reason R are correct statements, and R is the correct explanation of A.

12. Ans. (A)

Explanation

When the ball is falling with a constant velocity, it means the net force acting on the ball is zero. This is because it's in a state of dynamic equilibrium - the downward force equals the upward force.

The downward force is the gravitational force (weight of the ball), which is given by $F_g = Mg$.

The upward force is the sum of buoyant force and the viscous drag. The buoyant force is the weight of the fluid displaced by the ball, which is given by $F_b = Vg\rho_0 = Mg\rho_0/\rho$ where $V = M/\rho$ is the volume of the ball.

The viscous force, F_v, is the force that we need to find.

Since the net force is zero, we have:

$$F_g = F_b + F_v$$

or

$$Mg = Mg\rho_0/\rho + F_v$$

which simplifies to

$$F_v = Mg - Mg\rho_0/\rho = Mg(1 - \rho_0/\rho)$$

13. Ans. (C)

Explanation

The elongation of the wire can be calculated using the formula for stress and strain. The stress in the wire is given by:

$$\sigma = \frac{mg}{A}$$

where m is the mass of the block (4 kg), g is the acceleration due to gravity on the planet (1/4 of its value on the earth, or 2.5 m/s^2), and A is the cross-sectional area of the wire (3 mm^2).

The strain in the wire is given by:

$$\epsilon = \frac{\Delta L}{L}$$

where ΔL is the elongation of the wire and L is the original length of the wire (6 m).

Using Hooke's law, which states that stress is proportional to strain, we can find the elongation of the wire:

$$\sigma = Y\epsilon$$

where Y is the Young's modulus of the wire (2×10^{11} N/m^2).

Combining the above equations, we can find the elongation of the wire:

$$\epsilon = \frac{\sigma}{Y} = \frac{mg}{AY} = \frac{4\times2.5}{3\times10^{-6}\times2\times10^{11}} = \frac{5}{3\times10^{-6}\times10^{11}} = \frac{5}{3\times10^{5}}$$

$$\therefore \frac{\Delta L}{L} = \frac{5}{3\times10^{5}}$$

$$\Rightarrow \Delta L = \frac{5\times6}{3\times10^{5}} = \frac{1}{10^{4}} = 0.1 \text{ mm}$$

So, the elongation of the wire is 0.1 mm.

14. Ans. (C)

Explanation

Average kinetic energy of a molecule of gas

$$= \frac{f}{2}k_BT$$

f is degree of freedom.

15. Ans. (D)

Explanation

Initial surface energy $= 0.45 \times 4\pi\left(10^{-3}\right)^2$

$$\frac{4}{3}\pi\left(10^{-3}\right)^3 = 125 \times \frac{4\pi}{3} R_{\text{new}}^3$$

$$\therefore 10^{-3} = 5R_{\text{new}}$$

$$\therefore R_{\text{new}} \quad = \frac{10^{-3}}{5}\ \mathrm{m}$$

So, final surface energy $= 0.45 \times 125 \times 4\pi\left(\frac{10^{-3}}{5}\right)^2$

Increase in energy $= 0.45 \times 4\pi \times \left(10^{-3}\right)^2 \left[\frac{125}{25} - 1\right]$

$$= 4 \times 0.45 \times 4\pi \times 10^{-6}$$

$$= 2.26 \times 10^{-5}\ \mathrm{J}$$

16. Ans. (B)

Explanation

$$v=\sqrt{\frac{Y}{\rho}}=\sqrt{\frac{3.2\times10^{11}}{8\times10^{3}}}$$

$$=\sqrt{0.4\times10^{8}}$$

$$=\sqrt{40\times10^{6}}$$

$$=6.32\times10^{3}\ \mathrm{m/s}$$

17. Ans. (C)

$$\Delta\ell=\frac{F\ell}{SY}$$

F is same for both wire and $\Delta\ell$ is also same

$$\frac{\Delta\ell}{F}=\frac{\ell}{SY}$$

$$\Rightarrow\frac{\ell_A}{S_AY_A}=\frac{\ell_B}{S_BY_B}$$

$$\Rightarrow\frac{5}{2.5\times Y_A}=\frac{6}{3\times Y_B}$$

$$\Rightarrow\frac{Y_A}{Y_B}=1$$

18. Ans. (A)

Explanation

$$1000 \times \frac{4\pi}{3}(1)^3 = \frac{4\pi}{3}\mathrm{R}^3$$

$$\mathrm{R} = 10\,\mathrm{mm}$$

$$\mathrm{T} \times 1000 \times 4\pi\left(10^{-3}\right)^2 - \mathrm{T} \times 4\pi\left(10 \times 10^{-3}\right)^2 = \Delta\mathrm{E}$$

$$\Rightarrow \Delta\mathrm{E} = 4 \times \pi \times 7 \times 10^{-2}[1000 - 100] \times 10^{-6}$$

$$\Rightarrow \Delta\mathrm{E} = 7.92 \times 10^{-4}\,\mathrm{J}$$

19. Ans. (A)

Explanation

$$\because \Delta l = \frac{Fl(4)}{Y\pi d^2}$$

$$\frac{\Delta l_1}{\Delta l_2} = \frac{\Delta l_1}{d_1^2} \times \frac{d_2^2}{l_2}$$

$$\frac{0.2}{\Delta l_2} = \frac{1}{2} \times (2.4)^2$$

$$\Delta l_2 = \frac{2 \times 0.2}{(2.4)^2}$$

$$= 6.9 \times 10^{-2}\,\mathrm{mm}$$

20. Ans. (A)

Explanation

height of capillary rise $= \frac{2s\cos\theta}{\rho g R}$

When in A 5 cm $= \frac{2s_A\cos\theta}{\rho_A g R}$

When in B $h = \frac{2s_B \cos\theta}{\rho_B g R}$

$s_B = 2s_A$ and $\rho_B = 2\rho_A$

$h = \frac{2\times 2s_A \times \cos\theta}{2\rho_A g R} = 5$ cm

21. Ans. (B)

Explanation

Poisson ratio (σ), bulk modulus (K) and modulus of rigidity (η) are related by

$$\because 2\eta(1+\sigma) = 3K(1-2\sigma)$$

$$2\eta + 2\eta\sigma = 3K - 6K\sigma$$

$$\sigma = \frac{3K-2\eta}{2\eta+6K}$$

22. Ans. (D)

Explanation

Velocity of aircraft = 1050 km/h = 300 m/s

Now, weight of aircraft = ΔPA

$$\Delta P = \frac{5.4\times 10^5 \times g}{500} = 10800 \text{ Pa}$$

From Bernoulli's principle

$$\Delta P = \frac{1}{2}\rho\left[V_{upper}^2 - V_{lower}^2\right]$$

$$10800=\frac{1}{2}\times 1.2\times V_{lower}^2\left[\left(\frac{V_{upper}}{V_{lower}}\right)^2-1\right]$$

$$\left(\frac{V_{upper}}{V_{lower}}\right)^2=1+\frac{10800\times 2}{1.2\times(300)^2}=1.2$$

$$\frac{V_{upper}}{V_{lower}}=1.096$$

$\Rightarrow$ Fractional increases = 9.6%

23. Ans. (A)

Explanation

Surface area of soap bubble $=2\times 4\pi\mathrm{R}^2$ Work done $=$ change in surface energy $\times\mathrm{T_S}$

$$=\mathrm{T_S}\times 8\pi\times\left(\mathrm{R}_2^2-\mathrm{R}_1^2\right)$$

$$=2\times 10^{-2}\times 8\times\frac{22}{7}\times 49\times\frac{3}{4}\times 10^{-4}$$

$$=18.48\times 10^{-4}\,\mathrm{J}$$

24. Ans. (D)

Explanation

$$\mathrm{P}_{\text{in}}=270\mathrm{kPa},\mathrm{T}_{\text{in}}=27^{\circ}\mathrm{C}$$

$$=300\,\mathrm{K}$$

$$\mathrm{T}_{\text{final}}=36^{\circ}\mathrm{C}=309\,\mathrm{K}$$

Hence we can consider process to be isochoric volume constant

$$\therefore P \propto T$$

$$\frac{P_{\text{in}}}{P_f} = \frac{T_{\text{in}}}{T_f} \Rightarrow P_f = 278\,\text{kPa}$$

25. Ans. (A)

Explanation

(A) Surface Tension $= \frac{\mathrm{F}}{\ell} = \frac{\mathrm{MLT}^{-2}}{\mathrm{L}} = \mathrm{ML}^0\,\mathrm{T}^{-2}$

$$= \mathrm{kg\,s}^{-2}(\mathrm{IV})$$

(B) Pressure $= \frac{F}{\mathrm{A}} = \frac{\mathrm{MLT}^{-2}}{\mathrm{L}^2}$

$= \mathrm{kg\,m}^{-1}\,\mathrm{s}^{-2}(\mathrm{III})$

(C) Viscosity $= \frac{\mathrm{F}}{\mathrm{A}\left(\frac{\mathrm{dV}}{\mathrm{dz}}\right)} = \frac{\mathrm{MLT}^{-2}}{\mathrm{L}^2\left(\frac{\mathrm{LT}^{-1}}{\mathrm{L}}\right)}$

$$= \mathrm{ML}^{-1}\,\mathrm{T}^{-1} = \mathrm{kg\,m}^{-1}\,\mathrm{s}^{-1}(\mathrm{I})$$

(D) Impulse $= \int F dt = \mathrm{MLT}^{-2} \times \mathrm{T}$

$$= \mathrm{MLT}^{-1} = \mathrm{kg\,ms}^{-1}\ \text{(II)}$$

26. Ans. (A)

Explanation

Assertion A states that steel is used in the construction of buildings and bridges, which is true. Steel is a widely used material for construction due to its high strength, durability, and resistance to corrosion.

Reason R states that steel is more elastic and has a higher elastic limit compared to other common construction materials like concrete, and this is why it is preferred in construction. This statement is also true. Steel's high elasticity and high elastic limit make it an ideal material for use in construction as it can withstand greater stress before it becomes permanently deformed.

Therefore, both **Assertion A** and **Reason R** are true statements. However, to determine the most appropriate answer, we need to see if **Reason R** explains **Assertion A**.

Reason R does indeed explain why steel is used in the construction of buildings and bridges. Its high elasticity and high elastic limit allow it to withstand greater stress than other common construction materials before becoming permanently deformed, making it a preferred material for construction.

So, the correct answer is **Both A and R are correct, and R is the correct explanation of A**.

27. Ans. (B)

Explanation

$$[v]=\left[\mathrm{T}^{-1}\right]$$

$$[r]=\mathrm{L} \quad [s]=\left[\frac{\mathrm{MLT}^{-2}}{\mathrm{L}}\right]$$

$$[\rho]=\left[\frac{\mathrm{M}}{\mathrm{L}^3}\right]=\left[\mathrm{ML}^{-3}\right]$$

$$\Rightarrow v=r^a \rho^b \mathrm{s}^c$$

$$\Rightarrow \mathrm{T}^{-1}=\mathrm{L}^a \mathrm{M}^b \mathrm{L}^{-3b} \mathrm{M}^c \mathrm{T}^{-2c}$$

$$\Rightarrow \mathrm{T}^{-1}=\mathrm{M}^{(b+c)} \mathrm{L}^{(a-3b)} \mathrm{T}^{-2c}$$

$$-2c=-1 \Rightarrow c=\frac{1}{2}$$

$$b+c=0$$

$$\Rightarrow b=-\frac{1}{2}$$

$$a-3b=0 \Rightarrow 3b=a \Rightarrow a=-\frac{3}{2}$$

$$(a, b, c)=\left(-\frac{3}{2},-\frac{1}{2}, \frac{1}{2}\right)$$

28. Ans. (B)

Explanation

Elongation in wire $\delta = \frac{F\ell}{AY}$

$$\delta = \frac{250 \times 100}{6.25 \times 10^{-4} \times 10^{10}}$$

$$\delta = 4 \times 10^{-3}\ \mathrm{m}$$

2022
Numerical

Q.1. A tube of length 50 cm is filled completely with an incompressible liquid of mass 250 g and closed at both ends. The tube is then rotated in horizontal plane about one of its ends with a uniform angular velocity $x\sqrt{F}\,\mathrm{rad\,s^{-1}}$. If F be the force exerted by the liquid at the other end then the value of x will be _________.

JEE Main 2022 (Online) 29th July Evening Shift

Q.2. A metal wire of length 0.5 m and cross-sectional area 10^{-4} $\mathrm{m^2}$ has breaking stress $5\times108\mathrm{Nm^{-2}}$. A block of 10 kg is attached at one end of the string and is rotating in a horizontal circle. The maximum linear velocity of block will be ________ $\mathrm{ms^{-1}}$.

JEE Main 2022 (Online) 29th July Evening Shift

Q.3. The velocity of a small ball of mass 0.3 g and density 8 g/cc when dropped in a container filled with glycerine becomes constant after some time. If the density of glycerine is 1.3 g/cc, then the value of viscous force acting on the ball will be X×10−4 N, The value of X is ________.

$[\text{use g} = 10\,\mathrm{m/s^2}]$

JEE Main 2022 (Online) 29th July Evening Shift

Q4. The speed of a transverse wave passing through a string of length 50 cm and mass 10 g is 60 ms−1. The area of cross-section of the wire is 2.0 mm2 and its Young's modulus is 1.2×1011Nm−2. The extension of the wire over its natural length due to its tension will be X×10−5 m. The value of X is ________.

JEE Main 2022 (Online) 29th July Evening Shift

Q.5. A string of area of cross-section 4 mm2 and length 0.5 m is connected with a rigid body of mass 2 kg. The body is rotated in a vertical circular path of radius 0.5 m. The body acquires a speed of 5 m/s at the bottom of the circular path. Strain produced in the string when the body is at the bottom of the circle is ________ $\times10^{-5}$.

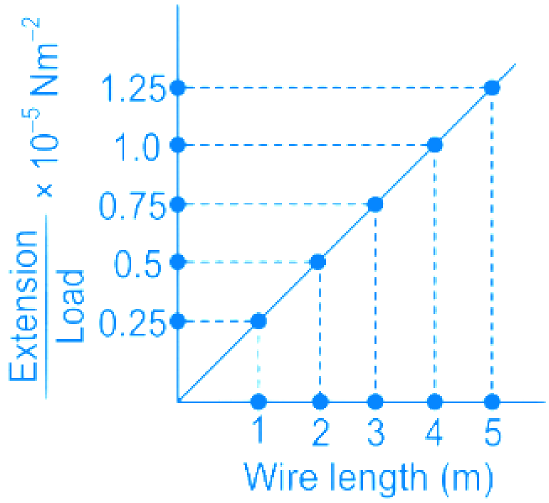
(use Young's modulus $10^{11}\ \mathrm{N/m^2}$ and $\mathrm{g} = 10\ \mathrm{m/s^2}$)

JEE Main 2022 (Online) 28th July Evening Shift

Q.6. The diameter of an air bubble which was initially 2 mm, rises steadily through a solution of density 1750 kg m−3 at the rate of 0.35cms−1. The coefficient of viscosity of the solution is ________ poise (in nearest integer). (The density of air is negligible).

JEE Main 2022 (Online) 28th July Morning Shift

Q.7. In an experiment to determine the Young's modulus, steel wires of five different lengths (1,2,3,4, and 5 m) but of same cross section (2 mm2) were taken and curves between extension and load were obtained. The slope (extension/load) of the curves were plotted with the wire length and the following graph is obtained. If the Young's modulus of given steel wires is X×1011Nm−2, then the value of X is ________.



JEE Main 2022 (Online) 27th July Evening Shift

Q.8. A spherical soap bubble of radius 3 cm is formed inside another spherical soap bubble of radius 6 cm. If the internal pressure of the smaller bubble of radius 3 cm in the above system is equal to the internal pressure of another single soap bubble of radius r cm. The value of r is __________.

JEE Main 2022 (Online) 27th July Evening Shift

Q.9. A square aluminum (shear modulus is 25×109Nm^{-2}) slab of side 60 cm and thickness 15 cm is subjected to a shearing force (on its narrow face) of 18.0×10^{4} N. The lower edge is riveted to the floor. The displacement of the upper edge is __________ µm.

JEE Main 2022 (Online) 27th July Morning Shift

Q.10. A uniform heavy rod of mass 20 kg, cross sectional area 0.4 m2 and length 20 m is hanging from a fixed support. Neglecting the lateral contraction, the elongation in the rod due to its own weight is $X \times 10^{-9}$ m. The value of X is ______________.

(Given, young modulus $Y = 2 \times 10^{11}\ \text{Nm}^{-2}$ and $g = 10\ \text{ms}^{-2}$)

JEE Main 2022 (Online) 26th July Evening Shift

Q.11. In an experiment to determine the Young's modulus of wire of a length exactly 1 m, the extension in the length of the wire is measured as 0.4 mm with an uncertainty of ±0.02 mm when a load of 1 kg is applied. The diameter of the wire is measured as 0.4 mm with an uncertainty of ±0.01 mm. The error in the measurement of Young's modulus (ΔY) is found to be X×1010Nm−2. The value of X is ________________.
(take $g = 10\ \text{ms}^{-2}$)

JEE Main 2022 (Online) 26th July Morning Shift

Q.12. A wire of length L and radius r is clamped rigidly at one end. When the other end of the wire is pulled by a force F, its length increases by 5 cm. Another wire of the same material of length 4L and radius 4r is pulled by a force 4F under same conditions. The increase in length of this wire is _________________ cm.

JEE Main 2022 (Online) 25th July Morning Shift

Q.13. A unit scale is to be prepared whose length does not change with temperature and remains 20 cm, using a bimetallic strip made of brass and iron each of different length. The length of both components would change in such a way that difference between their lengths remains constant. If length of brass is 40 cm and length of iron will be __________ cm.
$\left(\alpha_{\text{iron}} = 1.2 \times 10^{-5}\,\text{K}^{-1} \text{ and } \alpha_{\text{brass}} = 1.8 \times 10^{-5}\,\text{K}^{-1}\right)$.

JEE Main 2022 (Online) 25th July Morning Shift

Q.14. The excess pressure inside a liquid drop is 500 Nm^{-2}. If the radius of the drop is 2 mm, the surface tension of liquid is $x \times 10^{-3}\ \text{Nm}^{-1}$. The value of x is _____________.

JEE Main 2022 (Online) 30th June Morning Shift

Q.15. A small spherical ball of radius 0.1 mm and density 10^4 kg m^{-3} falls freely under gravity through a distance h before entering a tank of water. If, after entering the water the velocity of ball does not change and it continue to fall with same constant velocity inside water, then the value of h will be ___________ m.

(Given g = 10 ms^{-2}, viscosity of water = 1.0×10^{-5} N-sm^{-2}).

JEE Main 2022 (Online) 29th June Evening Shift

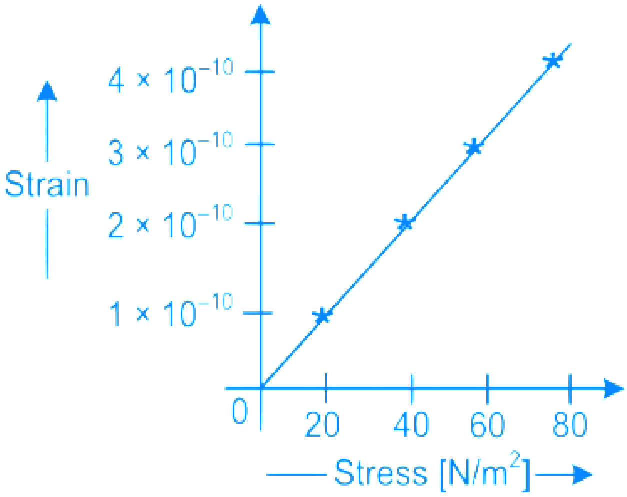
Q.16. A liquid of density 750 kgm^{-3} flows smoothly through a horizontal pipe that tapers in cross-sectional area from $A_1 = 1.2 \times 10^{-2}$ m^2 to A_2 = A1/2. The pressure difference between the wide and narrow sections of the pipe is 4500 Pa. The rate of flow of liquid is ___________ $\times 10^{-3}$ m^3s^{-1}.

JEE Main 2022 (Online) 28th June Evening Shift

Q.17. The area of cross-section of a large tank is 0.5 m^2. It has a narrow opening near the bottom having area of cross-section 1 cm^2. A load of 25 kg is applied on the water at the top in the tank. Neglecting the speed of water in the tank, the velocity of the water, coming out of the opening at the time when the height of water level in the tank is 40 cm above the bottom, will be ___________ cms^{-1}. [Take g = 10 ms^{-2}]

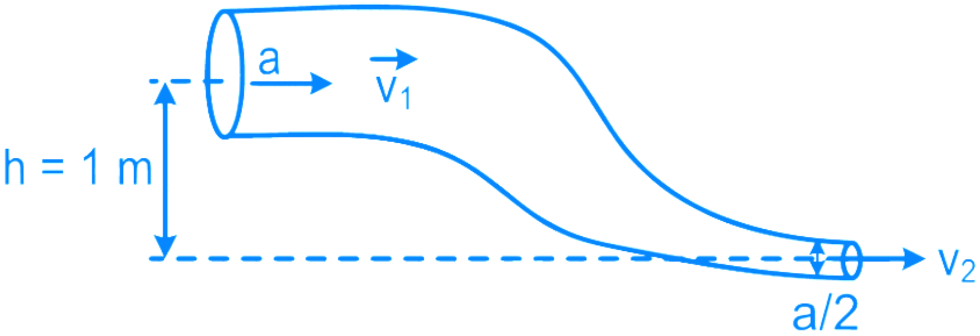
JEE Main 2022 (Online) 27th June Morning Shift

Q.18. The elastic behaviour of material for linear stress and linear strain, is shown in the figure. The energy density for a linear strain of 5×10^{-4} is ___________ kJ/m^3. Assume that material is elastic upto the linear strain of 5×10^{-4}.



JEE Main 2022 (Online) 26th June Morning Shift

Q.19. An ideal fluid of density 800 kgm^{-3}, flows smoothly through a bent pipe (as shown in figure) that tapers in cross-sectional area from a to a/2. The pressure difference between the wide and narrow sections of pipe is 4100 Pa. At wider section, the velocity of fluid is x/6 ms^{-1} for x = ___________. (Given g = 10 ms^{-2})



JEE Main 2022 (Online) 26th June Morning Shift

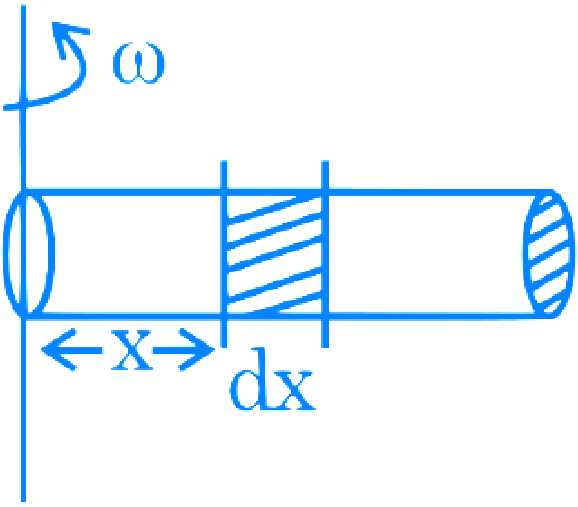
Q.20. The velocity of upper layer of water in a river is 36 kmh^{-1}. Shearing stress between horizontal layers of water is 10^{-3} Nm^{-2}. Depth of the river is __________ m. (Co-efficient of viscosity of water is 10^{-2} Pa.s)

JEE Main 2022 (Online) 25th June Morning Shift

Answer Key & Explanation

1. Ans. Correct answer is 4

Explanation



$$F = \int (dm)\omega^2 x$$

$$= \int_0^L \left(\frac{m}{L}dx\right)\omega^2 x$$

$$= \frac{m}{L}\omega^2\frac{L^2}{2}$$

$$= \frac{m\omega^2 L}{2}$$

$$\omega = \sqrt{\frac{2}{mL}}\sqrt{F}$$

$$= \sqrt{\frac{2}{0.25 \times 0.5}}\sqrt{F}$$

$$= \sqrt{16}\sqrt{F}$$

$$= 4\sqrt{F}$$

2. Ans. Correct answer is 50

Explanation

$$\mathrm{T}=\frac{\mathrm{mv}^2}{\ell}=\frac{10\times \mathrm{v}^2}{0.5}=20\mathrm{v}^2$$

$$\mathrm{T}_{\max}=\text{Breaking stress}\times\text{Area}$$

$$=5\times 10^8\times 10^{-4}=5\times 10^4$$

$$20\,\mathrm{V}^2=5\times 10^4$$

$$\mathrm{V}=\sqrt{\frac{1}{4}\times 10^4}=50\,\mathrm{m/s}$$

3. Ans. Correct answer is 25

Explanation

$$F_{\mathrm{V}}+F_B=mg(v=\text{constant})$$

$$F_V=mg-F_B$$

$$=\rho_{\mathrm{B}}\mathrm{Vg}-\rho_{\mathrm{L}}\mathrm{Vg}$$

$$=(\rho_{\mathrm{B}}-\rho_{\mathrm{L}})\mathrm{Vg}$$

$$=(8-1.3)\times 10^{+3}\times\frac{0.3\times 10^{-3}}{8\times 10^3}\times 10$$

$$=\frac{6.7\times 0.3}{8}\times 10^{-2}\quad(\mathrm{g}=10)$$

$$=\frac{67\times 3}{8}\times 10^{-4}=25.125\times 10^{-4}$$

4. Ans. Correct answer is 15

Explanation

$$\mathrm{V_w} = \sqrt{\frac{\mathrm{T}}{\mu}}$$

$$60 = \sqrt{\frac{\mathrm{T}}{10\times10^{-3}} \times 0.5}$$

$$\mathrm{T} = \frac{(60)^2\times10^{-2}}{0.5} = 72\,\mathrm{N}$$

$$\Delta\ell = \frac{\mathrm{F}\ell}{\mathrm{AY}} = \frac{72\times0.5}{2\times10^{-6}\times1.2\times10^{11}}$$

$$= \frac{72\times5}{24} \times 10^{-5} = 15 \times 10^{-5}$$

5. Ans. Correct answer is 30

Explanation

$$A = 4 \times 10^{-6}\,\mathrm{m}^2$$

$$l = 0.5\,\mathrm{m}$$

$$m = 2\,\mathrm{kg}$$

$$v_b = 5\,\mathrm{m/s}$$

$$T_b = mg + m\left(\frac{V_b^2}{l}\right)$$

$$= 20 + 2 \times \frac{25}{\frac{1}{2}} = 120\,\mathrm{N}$$

$$\frac{\Delta l}{l} = \frac{T_b}{A} \times \frac{1}{Y} = \frac{120}{4\times10^{-6}} \times 10^{-11} = 30 \times 10^{-5}$$

6. Ans. Correct answer is 11

Explanation

$$F=6\pi\eta r v$$

$$\frac{4}{3}\pi r^3\rho_l g=6\pi\eta r v$$

$$\eta=\frac{2r^2\rho_l g}{v}$$

$$=\frac{2\times(2\times10^{-3})^2\times1750\times10}{9\times3.5\times10^{-3}\times4}$$

$$=11\text{ poise}$$

7. Ans. Correct answer is 2

Explanation

$$Y=\frac{F\times l}{A\times\Delta l}$$

$$=\frac{1}{A}\times\frac{Wire\ length}{\frac{Extension}{load}}$$

$$Y=\frac{1}{A}\times\left(\frac{1}{0.25\times10^{-5}}\right)$$

$$Y=10^{11}\times2$$

$$\Rightarrow x=2$$

8. Ans. Correct answer is 2

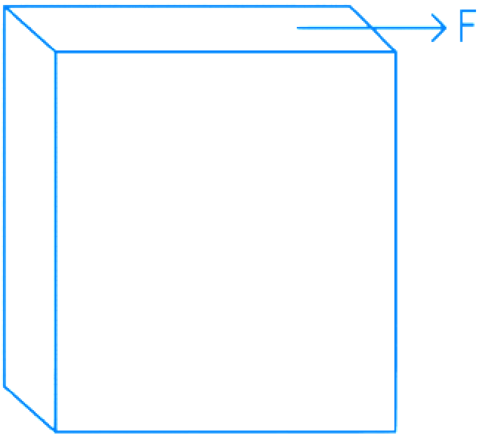
Explanation

$$\frac{4T}{R_1}+\frac{4T}{R_2}=\frac{4T}{r}$$

$$\Rightarrow\frac{1}{r}=\frac{1}{3}+\frac{1}{6}\Rightarrow r=2\text{ cm}$$

9. Ans. Correct answer is 48

Explanation



$$Y = \frac{Fl}{A\Delta l}$$

$$\Delta l = \frac{Fl}{YA}$$

$$= \frac{18\times10^{4}\times60\times10^{-2}}{25\times10^{9}\times60\times15\times10^{-4}}$$

$$= 48 \times 10^{-6} \text{ m}$$

10. Ans. Correct answer is 25

Explanation

$$\frac{\frac{F}{A}}{\frac{\Delta L}{L}} = Y$$

$$\Delta L = \frac{FL}{AY} = \frac{T_{avg}L}{AY} = \frac{MgL}{2AY}$$

$$= \frac{20\times10\times20}{2\times0.4\times2\times10^{11}} = \frac{4\times10^{3}\times10^{-11}}{4\times0.4}$$

$$= 2.5 \times 10^{-8} = 25 \times 10^{-9}$$

11. Ans. Correct answer is 2

Explanation

$$\frac{F/A}{l/L} = Y,\ A = \pi D^2$$

$$\frac{\Delta Y}{Y} = \frac{\Delta F}{F} + \frac{2\Delta D}{D} + \frac{\Delta l}{e} + \frac{\Delta L}{L}$$

$$= 2 \times \frac{0.01}{0.4} + \frac{0.02}{0.4}$$

$$= \frac{0.04}{0.4} = \frac{1}{10}$$

$$Y = \frac{Fl}{A\Delta l}$$

$$= \frac{10\times1}{\pi(0.1\,mm)^2\times0.4\,mm}$$

$$= 1.988 \times 10^{11}$$

$$\approx 2 \times 10^{11}$$

$$\frac{\Delta y}{y} = \frac{1}{10}$$

$$\Delta y = \frac{y}{10} = 2 \times 10^{10}$$

12. Ans. Correct answer is 5

Explanation

$$\frac{F/A}{\Delta L/L} = Y$$

$$\Rightarrow \Delta L = \frac{FL}{AY}$$

$$\frac{\Delta L_2}{\Delta L_1} = \left(\frac{F_2}{F_1}\right) \times \left(\frac{L_2}{L_1}\right) \times \left(\frac{A_1}{A_2}\right)$$

$$= 4 \times 4 \times \frac{1}{16} = 1$$

$$\Delta L_2 = \Delta L_1 = 5 \text{ cm.}$$

13. Ans. Correct answer is 60

Explanation

$$\Delta L_1 = \alpha_1 L_1 \Delta T$$

$$\Delta L_2 = \alpha_2 L_2 \Delta T$$

$\alpha_1 L_1 = \alpha_2 L_2$

$1.2 \times 10^{-5} \times L_1 = 1.8 \times 10^{-5} \times L_2$

$L_1 = \frac{1.8}{1.2} \times 40 = 60$ cm

14. Ans. Correct answer is 500

Explanation

$\mathrm{P} = \mathrm{P}_0 + \frac{2T}{R}$

$\Rightarrow P - P_0 = \frac{2T}{R}$

$$500 = \frac{2 \times T}{2 \times 10^{-3}}$$

$T = 500 \times 10^{-3}$

So, $x = 500$

15. Ans. Correct answer is 20

Explanation

$\sqrt{2gh}$ = terminal speed

$\Rightarrow \sqrt{2gh} = \frac{2}{9} \frac{r^2 g(\rho - \rho')}{\eta}$

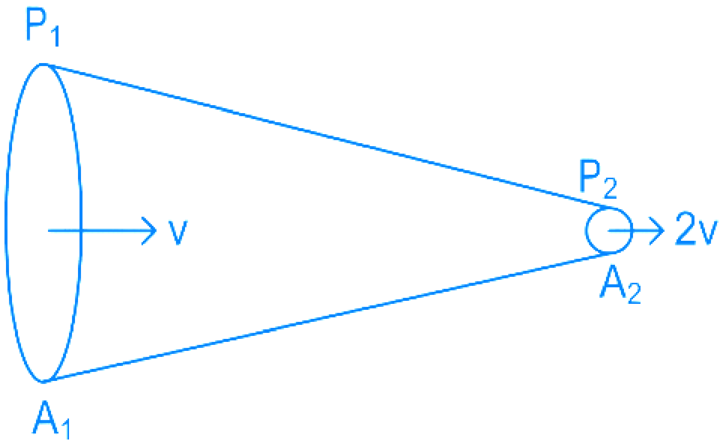
$= \frac{2}{9} \times \frac{10^{-8} \times 10 \times 9000}{10^{-5}}$

$\Rightarrow h = \frac{400}{2g}$

$\Rightarrow h = 20$ m

16. Ans. Correct answer is 24

Explanation



Using Bernoulli's equation

$$P_1 + \frac{1}{2}\rho v^2 = P_2 + \frac{1}{2}\rho 4v^2$$

$$\frac{3}{2}\rho v^2 = P_1 - P_2$$

$$\Rightarrow v = \sqrt{\frac{2(P_1 - P_2)}{3\rho}}$$

$$= \sqrt{\frac{2\times 4500}{3\times 750}} = 2 \text{ m/sec}$$

So $Q = A_1 v = 24 \times 10^{-3}$ m^3/sec

17. Ans. Correct answer is 300

Explanation

By Bernoulli's theorem:

$$\frac{250}{0.5} + \rho g h = \frac{1}{2}\rho v^2$$

$\Rightarrow$ v = 3 m/s

$\Rightarrow$ v = 300 cm/s

18. Ans. Correct answer is 25

Explanation

slope of strain $-$ stress curve given by $= \frac{10^{-10}}{20}$

for strain of 5×10^{-4} stress is given by

$5 \times 10^{-4} = \frac{10^{-10}}{20} \times$ stress

stress = 10^8 N/m^2

Energy density $= \frac{1}{2} \times$ strain $\times$ stress

$= \frac{1}{2} \times 5 \times 10^{-4} \times 10^8$

$= 25000$ J/m^3

$= 25$ kJ/m^3

19. Ans. Correct answer is 363

Explanation

From Bernoulli's equation

$$P_1 + \frac{1}{2}\rho {v_1}^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho {v_2}^2 + \rho g h_2$$

$$P_1 - P_2 + \rho g(h_1 - h_2) = \frac{1}{2}\rho({v_2}^2 - {v_1}^2) \text{ ...... (i)}$$

Also, from equation of continuity

$$A_1 v_1 = A_2 v_2$$

$$A v_1 = \frac{A}{2} v_2$$

$$v_2 = 2v_1 \text{ ...... (ii)}$$

put equation (ii) in (i),

$$4100 \times 800 \times 10 \times 1 = \frac{1}{2} \times 800 \times (4{v_1}^2 - {v_1}^2)$$

$$4100 + 8000 = 400 \times 3{v_1}^2$$

$${v_1}^2 = \frac{12100}{3 \times 400} = \frac{121}{12}$$

$$v_1 = \sqrt{\frac{121}{12}}$$

Now, $\frac{\sqrt{x}}{6} = \sqrt{\frac{121}{12}}$

$$\frac{x}{36} = \frac{121}{12}$$

$$x = 121 \times 3 = 363$$

$$\therefore x = 363$$

20. Ans. Correct answer is 100

Explanation

$$F = -\eta A \frac{du}{dx}$$

$$\Rightarrow 10^{-3} = 10^{-2} \times \frac{10}{h}$$

$\Rightarrow h = \frac{10^{-1}}{10^{-3}}$ m = 100 m

$\Rightarrow$ (100)

MCQ (Single Correct Answer)

Q.1. Given below are two statements : One is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A): Clothes containing oil or grease stains cannot be cleaned by water wash.

Reason (R): Because the angle of contact between the oil/grease and water is obtuse.

In the light of the above statements, choose the correct answer from the option given below.

A Both (A) and (R) are true and (R) is the correct explanation of (A)

B Both (A) and (R) are true but (R) is not the correct explanation of (A)

C (A) is true but (R) is false

D (A) is false but (R) is true

JEE Main 2022 (Online) 29th July Morning Shift

Q.2. If the length of a wire is made double and radius is halved of its respective values. Then, the Young's modulus of the material of the wire will :

A remain same

B become 8 times its initial value

C become $\frac{1}{4}$ of its initial value

D become 4 times its initial value

JEE Main 2022 (Online) 29th July Morning Shift

Q.3. A pressure-pump has a horizontal tube of cross sectional area $10\ \text{cm}^2$ for the outflow of water at a speed of $20\ \text{m/s}$. The force exerted on the vertical wall just in front of the tube which stops water horizontally flowing out of the tube, is :

[given: density of water $= 1000\,\mathrm{kg/m^3}$]

Ⓐ 300 N

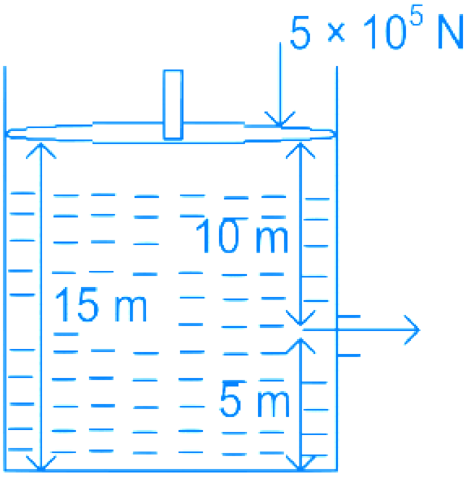
Ⓑ 500 N

Ⓒ 250 N

Ⓓ 400 N

JEE Main 2022 (Online) 28th July Evening Shift

Q.4. Consider a cylindrical tank of radius 1 m is filled with water. The top surface of water is at 15 m from the bottom of the cylinder. There is a hole on the wall of cylinder at a height of 5 m from the bottom. A force of 5×10^5 N is applied an the top surface of water using a piston. The speed of ifflux from the hole will be : (given atmospheric pressure $PA=1.01\times10^5$ Pa, density of water $pW=1000\ \text{kg/m}^3$ and gravitational acceleration $g=10\ \text{m/s}^2$)



Ⓐ 11.6 m/s

Ⓑ 10.8 m/s

Ⓒ 17.8 m/s

Ⓓ 14.4 m/s

JEE Main 2022 (Online) 28th July Evening Shift

Q.5. A balloon has mass of $10 \mathrm{~g}$ in air. The air escapes from the balloon at a uniform rate with velocity $4.5 \mathrm{~cm/s}$. If the balloon shrinks in $5 \mathrm{~s}$ completely. Then, the average force acting on that balloon will be (in dyne).

Ⓐ 3

Ⓑ 9

Ⓒ 12

Ⓓ 18

JEE Main 2022 (Online) 28th July Morning Shift

Q.6. The force required to stretch a wire of cross-section $1 \mathrm{~cm}^2$ to double its length will be : (Given Yong's modulus of the wire $=2 \times 10^{11} \mathrm{~N/m}^2$)

A 1×10^7 N

B 1.5×10^7 N

C 2×10^7 N

D 2.5×10^7 N

JEE Main 2022 (Online) 28th July Morning Shift

Q.7. A steel wire of length 3.2 m($Ys=2.0\times10^{11}Nm^{-2}$) and a copper wire of length 4.4 m($Yc=1.1\times10^{1}1Nm^{-2}$), both of radius 1.4 mm are connected end to end. When stretched by a load, the net elongation is found to be 1.4 mm. The load applied, in Newton, will be:

A 360

B 180

C 1080

D 154

JEE Main 2022 (Online) 27th July Evening Shift

Q.8. wo cylindrical vessels of equal cross-sectional area 16 cm2 contain water upto heights 100 cm and 150 cm respectively. The vessels are interconnected so that the water levels in them become equal. The work done by the force of gravity during the process, is [Take, density of water =103 kg/m3 and $g=10\ ms^{-2}$] :

Ⓐ 0.25 J

Ⓑ 1 J

Ⓒ 8 J

Ⓓ 12 J

JEE Main 2022 (Online) 27th July Morning Shift

Q.9. The area of cross section of the rope used to lift a load by a crane is 2.5×10−4 m2. The maximum lifting capacity of the crane is 10 metric tons. To increase the lifting capacity of the crane to 25 metric tons, the required area of cross section of the rope should be:

(take $g = 10\,ms^{-2}$)

Ⓐ $6.25 \times 10^{-4}\,\mathrm{m}^2$

Ⓑ $10 \times 10^{-4}\,\mathrm{m}^2$

Ⓒ $1 \times 10^{-4}\,\mathrm{m}^2$

Ⓓ $1.67 \times 10^{-4}\,\mathrm{m}^2$

JEE Main 2022 (Online) 26th July Evening Shift

Q.10. A water drop of radius 1 cm is broken into 729 equal droplets. If surface tension of water is 75 dyne/ cm, then the gain in surface energy upto first decimal place will be :

(Given $\pi = 3.14$)

A $8.5 \times 10^{-4}\ \mathrm{J}$

B $8.2 \times 10^{-4}\ \mathrm{J}$

C $7.5 \times 10^{-4}\ \mathrm{J}$

D $5.3 \times 10^{-4}\ \mathrm{J}$

JEE Main 2022 (Online) 26th July Morning Shift

Q.11. A drop of liquid of density ρ is floating half immersed in a liquid of density σ and surface tension 7.5×10−4 Ncm^{-1}. The radius of drop in cm will be: $(g = 10\ \mathrm{ms}^{-2})$

A $\frac{15}{\sqrt{(2\rho - \sigma)}}$

B $\frac{15}{\sqrt{(\rho - \sigma)}}$

C $\frac{3}{2\sqrt{(\rho - \sigma)}}$

D $\frac{3}{20\sqrt{(2\rho - \sigma)}}$

JEE Main 2022 (Online) 25th July Evening Shift

Q.12. An air bubble of negligible weight having radius r rises steadily through a solution of density σ at speed v. The coefficient of viscosity of the solution is given by :

Ⓐ $\eta=\frac{4r\sigma g}{9v}$

Ⓑ $\eta=\frac{2r^2\sigma g}{9v}$

Ⓒ $\eta=\frac{2\pi r^2\sigma g}{9v}$

Ⓓ $\eta=\frac{2r^2\sigma g}{3\pi v}$

JEE Main 2022 (Online) 30th June Morning Shift

Q.13. A wire of length L is hanging from a fixed support. The length changes to L_1 and L_2 when masses 1 kg and 2 kg are suspended respectively from its free end. Then the value of L is equal to :

Ⓐ $\sqrt{L_1L_2}$

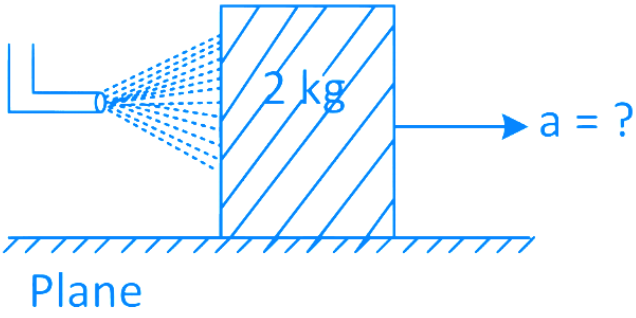
Ⓑ $\frac{L_1+L_2}{2}$

Ⓒ $2L_1-L_2$

Ⓓ $3L_1-2L_2$

JEE Main 2022 (Online) 29th June Morning Shift

Q.14. A block of metal weighing 2 kg is resting on a frictionless plane (as shown in figure). It is struck by a jet releasing water at a rate of 1 kgs^{-1} and at a speed of 10 ms^{-1}. Then, the initial acceleration of the block, in ms^{-2}, will be :



Ⓐ 3

Ⓑ 6

Ⓒ 5

Ⓓ 4

JEE Main 2022 (Online) 29th June Morning Shift

Q.15. A water drop of radius 1 μm falls in a situation where the effect of buoyant force is negligible. Co-efficient of viscosity of air is 1.8×10^{-5} Nsm^{-2} and its density is negligible as compared to that of water 10^{6} gm^{-3}. Terminal velocity of the water drop is :

(Take acceleration due to gravity = 10 ms^{-2})

Ⓐ $145.4 \times 10^{-6}\,ms^{-1}$

Ⓑ $118.0 \times 10^{-6}\,ms^{-1}$

Ⓒ $132.6 \times 10^{-6}\,ms^{-1}$

Ⓓ $123.4 \times 10^{-6}\,ms^{-1}$

JEE Main 2022 (Online) 28th June Evening Shift

Q.16. Given below are two statements : One is labelled as Assertion A and the other is labelled as Reason R.

Assertion A : Product of Pressure (P) and time (t) has the same dimension as that of coefficient of viscosity.

Reason R : Coefficient of viscosity $= \frac{Force}{Velocity\ gradient}$

Choose the correct answer from the options given below :

- Ⓐ Both A and R are true, and R is the correct explanation of A.
- Ⓑ Both A and R are true but R is NOT the correct explanation of A.
- Ⓒ A is true but R is false.
- Ⓓ A is false but R is true.

JEE Main 2022 (Online) 28th June Morning Shift

Q.17. A water drop of diameter 2 cm is broken into 64 equal droplets. The surface tension of water is 0.075 N/m. In this process the gain in surface energy will be :

- Ⓐ 2.8×10^{-4} J
- Ⓑ 1.5×10^{-3} J
- Ⓒ 1.9×10^{-4} J
- Ⓓ 9.4×10^{-5} J

JEE Main 2022 (Online) 28th June Morning Shift

Q.18. The velocity of a small ball of mass 'm' and density d_1, when dropped in a container filled with glycerin, becomes constant after some time. If the density of glycerin is d_2, then the viscous force acting on the ball, will be :

A $mg\left(1-\frac{d_1}{d_2}\right)$

B $mg\left(1-\frac{d_2}{d_1}\right)$

C $mg\left(\frac{d_1}{d_2}-1\right)$

D $mg\left(\frac{d_2}{d_1}-1\right)$

JEE Main 2022 (Online) 27th June Morning Shift

Q.19. If p is the density and η is coefficient of viscosity of fluid which flows with a speed v in the pipe of diameter d, the correct formula for Reynolds number R_e is :

A $R_e=\frac{\eta d}{\rho v}$

B $R_e=\frac{\rho v}{\eta d}$

C $R_e=\frac{\rho v d}{\eta}$

D $R_e=\frac{\eta}{\rho v d}$

JEE Main 2022 (Online) 26th June Evening Shift

Q.20. A solid metallic cube having total surface area 24 m^2 is uniformly heated. If its temperature is increased by $10^{\circ}C$, calculate the increase in volume of the cube. (Given $\alpha = 5.0 \times 10^{-4}\ {}^{\circ}C^{-1}$).

A 2.4×10^{6} cm^{3}

B 1.2×10^{5} cm^{3}

C 6.0×10^{4} cm^{3}

D 4.8×10^{5} cm^{3}

JEE Main 2022 (Online) 25th June Evening Shift

Q.21. The terminal velocity (v_t) of the spherical rain drop depends on the radius (r) of the spherical rain drop as :

A $r^{1/2}$

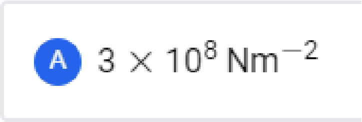
B r

C r^{2}

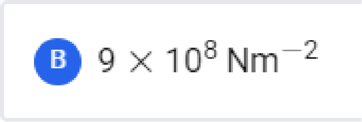
D r^{3}

JEE Main 2022 (Online) 25th June Morning Shift

Q.22. The bulk modulus of a liquid is 3×10^{10} Nm^{-2}. The pressure required to reduce the volume of liquid by 2% is :

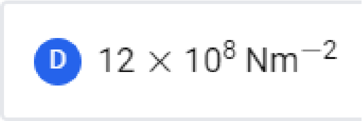


A $3 \times 10^8 \, \text{Nm}^{-2}$



B $9 \times 10^8 \, \text{Nm}^{-2}$

C $6 \times 10^8 \, \text{Nm}^{-2}$



D $12 \times 10^8 \, \text{Nm}^{-2}$

JEE Main 2022 (Online) 24th June Morning Shift

Answer Key & Explanation

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1. Ans. (A)

Explanation

Due to obtuse angle of contact the water doesn't wet the oiled surface properly and cannot wash it also.

⇒ Assertion is correct and Reason given is a correct explanation.

2. Ans. (A)

Explanation

Young's modulus of matter depends on material of wire and is independent of the dimensions of the wire. As the material remains same so Young's modulus also remain same.

3. Ans. (D)

Explanation

$$F_w = \rho A v^2$$

$$= 10^3 \times 10 \times 10^{-4} \times 20 \times 20$$

$$= 400\, N$$

4. Ans. (C)

Explanation

By Bernoulli's theorem,

$$\frac{5\times10^5}{\pi(1)^2} + \rho g(10) = 1.01 \times 10^5 + \frac{1}{2}\rho(v)^2$$

$$\Rightarrow v^2 = 200 + \frac{10^6}{1000\pi} - 202$$

$$\Rightarrow v \simeq 17.8 \text{ m/s}$$

5. Ans. (B)

Explanation

$$F_{avg} = \mu \times v_{rel}$$

$$= \frac{10}{5} \times 4.5 = 9$$

6. Ans. (C)

Explanation

$$A = 1 \text{ cm}^2$$

$$Y = \frac{Fl}{A\Delta l}$$

$$F = \frac{YA\Delta l}{l} = \frac{2\times10^{11}\times10^{-4}\times l}{l}$$

$$= 2 \times 10^7 \text{ N}$$

7. Ans. (D)

Explanation

$$\Delta l_s + \Delta l_c = 1.4$$

$$\frac{Wl_s}{Y_s \times A} + \frac{Wl_c}{Y_c \times A} = 1.4 \times 10^{-3}$$

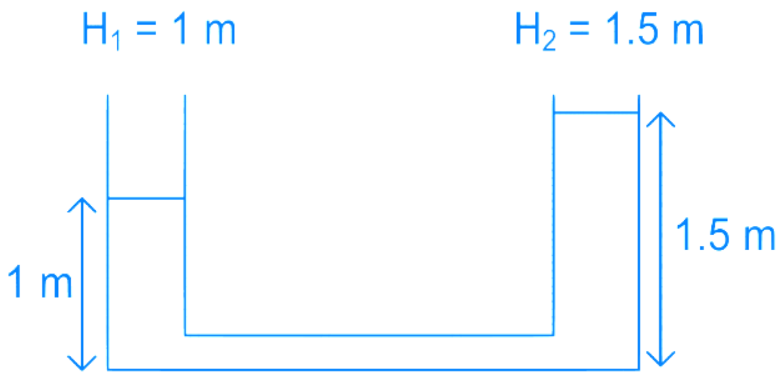
$$W = \frac{1.4 \times 10^{-3}}{\left[\frac{3.2}{2 \times (\pi \times 1.4 \times 10^{-3})^2} + \frac{4.4}{1.1 \times (\pi \times 1.4 \times 10^{-3})^2}\right] \frac{1}{10^{+11}}}$$

$$W \simeq 154\,N$$

8. Ans. (B)

Explanation

A=16×10^{-4} m^2



$$E_{in} = m_1 g \frac{H_1}{2} + m_2 g \frac{H_2}{2}$$

$$= \rho g \frac{A}{2}\left(H_1^2 + H_2^2\right) = \rho g \frac{A}{2}\left(1^2 + 1.5^2\right)$$

$$E_{fin} = \rho g \frac{A}{2}\left(2H^2\right) = \rho g \frac{A}{2}\left(2 \times 1.25^2\right)$$

$$W = \rho g \frac{A}{2}(3.25 - 3.125)$$

$$= 1\text{ J}$$

9. Ans. (A)

Explanation

The relationship between stress (σ), force (F), and area (A) is given by :

$$\sigma = \frac{F}{A}$$

In this context, the force is equal to the weight of the load, so we can substitute force with mass (m) times gravity (g) :

$$F = m \cdot g$$

From this, we get the formula for the cross-sectional area required to support a given mass :

$$A = \frac{F}{\sigma} = \frac{m \cdot g}{\sigma}$$

We can set up a proportionality relationship between the area for 10 metric tons (A_{10}) and the area for 25 metric tons (A_{25}) as follows :

$$\frac{A_{10}}{A_{25}} = \frac{m_{10}}{m_{25}}$$

Using the given values :

$A_{10} = 2.5 \times 10^{-4}$ m²,
$m_{10} = 10,000$ kg,
$m_{25} = 25,000$ kg,

Solving for A_{25} :

$$A_{25} = A_{10} \times \left(\frac{m_{25}}{m_{10}}\right) = 2.5 \times 10^{-4}\,\mathrm{m}^2 \times \left(\frac{25{,}000\ \mathrm{kg}}{10{,}000\ \mathrm{kg}}\right) = 6.25 \times 10^{-4}\,\mathrm{m}^2$$

So, Option A $(6.25 \times 10^{-4}\,\mathrm{m}^2)$ is the correct answer.

10. Ans. (C)

Explanation

$$729 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

$\Rightarrow R = 9r$ .... (1)

$\Delta U = S \times \Delta A$ ..... (2)

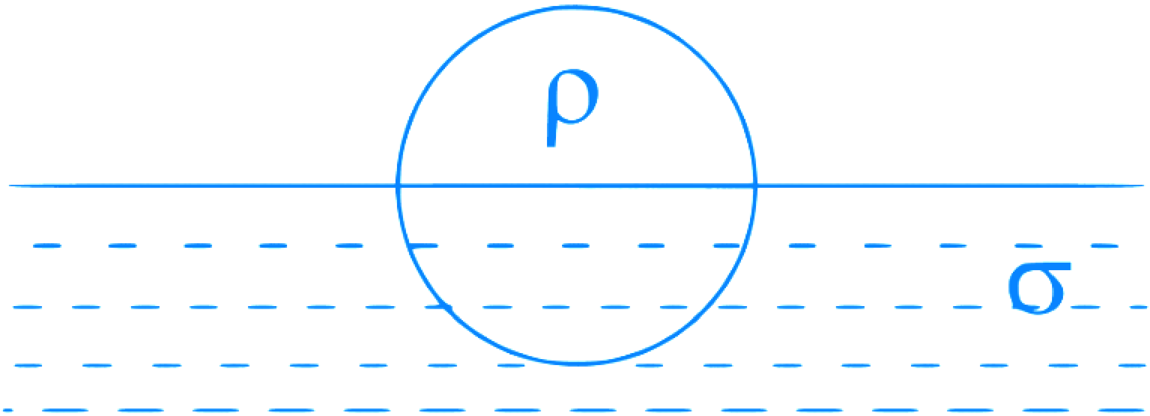
$$\Rightarrow \Delta U = S \times \{-4\pi R^2 + 729 \times 4\pi r^2\}$$

$$= S \times 4\pi\{729r^2 - 81r^2\}$$

$$= 7.5 \times 10^{-4}\,J$$

11. Ans. (A)

Explanation



At equilibrium, forces balance each other

$$\mathrm{S}(2\pi \mathrm{r})+\mathrm{F}_{\mathrm{b}}=mg$$

Where $S=$ surface tension

$$\mathrm{F}_{\mathrm{b}}= \text{ buoyant force } =\frac{2}{3}\pi r^{3}\sigma g$$

$$S(2\pi r)=mg-\mathrm{F}_{b}=\frac{4}{3}\pi r^{3}\left(p-\frac{\sigma}{2}\right)g$$

$$\Rightarrow r^{2}=\frac{3S}{(2p-\sigma)g}$$

$$\Rightarrow r^{2}=\frac{3\times 7.5\times 10^{-2}}{(2p-\sigma)10}$$

$$\Rightarrow r^{2}=\frac{22.5\times 10^{-2}}{(2p-\sigma)10}$$

$$\Rightarrow r=\frac{1.5\times 10^{-1}}{\sqrt{2p-\sigma}}\mathrm{m}$$

$$=\frac{15}{\sqrt{2p-\sigma}}\mathrm{cm}$$

12. Ans. (B)

Explanation

Air bubble moves with constant speed v. So net force = 0.

∴ Buoyant Force = Viscous force

$$\Rightarrow F_b = F_v$$

$$\Rightarrow \sigma \times \frac{4}{3}\pi r^3 g = 6\pi n r v$$

$$\Rightarrow n = \frac{2\sigma r^2 g}{9v}$$

13. Ans. (C)

Explanation

$$y = \frac{FL}{A\Delta L}$$

$$\Rightarrow \Delta L = \frac{FL}{Ay}$$

$$\Rightarrow L_1 = L + \frac{(1g)L}{Ay} \text{ ..... (i)}$$

and $L_2 = L + \frac{(2g)L}{Ay}$ ..... (ii)

$$\Rightarrow L = 2L_1 - L_2$$

14. Ans. (C)

Explanation

F = ρ v^{2}a

⇒ 10 × 1 = 2 × acceleration

⇒ Acc. = 5 m/s^2

15. Ans. (D)

Explanation

$6\pi\eta rv = mg$

$6\pi\eta rv = \frac{4}{3}\pi r^3\rho g$

or $v = \frac{2}{9}\frac{\rho r^2 g}{\eta} = \frac{2}{9} \times \frac{10^3 \times (10^{-6})^2 \times 10}{1.8 \times 10^{-5}}$

$= 123.4 \times 10^{-6}$ m/s

16. Ans. (C)

Explanation

[Pressure][Time] = $\left[\frac{Force}{Area}\right]\left[\frac{distance}{Area}\right]$

[Coefficient of viscosity] = $\left[\frac{Force}{Area}\right]\left[\frac{distance}{Area}\right]$

Statement 'A' is true

But Statement 'R' is false are coefficient of viscosity

$= \frac{Force}{Area \times Velocity\ gradient}$

17. Ans. (A)

Explanation

$r' = \frac{r}{4}$

$\Rightarrow \Delta E = T(\Delta S)$

$= T \times 4\pi(nr'^2 - r^2),\ n = 64$

$= T \times 4\pi \times (4-1)r^2$

$\Rightarrow \Delta E = 0.075 \times 4 \times 3.142(3) \times 10^{-4}$ J

$= 2.8 \times 10^{-4}$ J

18. Ans. (B)

Explanation

Viscous force acting on the ball will be equal and opposite to net of weight and buoyant force

$$\Rightarrow F_0 = \frac{4}{3}\pi r^3 d_1 g - \frac{4}{3}\pi r^3 d_2 g$$

$$= \frac{4}{3}\pi r^3 d_1 g\left(1 - \frac{d_2}{d_1}\right)$$

$$= mg\left(1 - \frac{d_2}{d_1}\right)$$

19. Ans. (C)

Explanation

$$R_e = \frac{\rho v d}{\eta}$$

Direct formula based

20. Ans. (B)

Explanation

$$6 \times l^2 = 24$$

$$\Rightarrow l = 2\text{ m}$$

$$\therefore \frac{\Delta V}{V} = 3 \times \frac{\Delta l}{l}$$

$$\Rightarrow \Delta V = 3 \times (\alpha \Delta T) \times V$$

$$= 3 \times 5 \times 10^{-4} \times 10 \times (8)$$

$$= 120 \times 10^{-3}\text{ m}^3$$

$$= 120 \times 10^{-3} \times 10^6\text{ cm}^3$$

$$= 1.2 \times 10^5\text{ cm}^3$$

21. Ans. (C)

Explanation

$6\pi\eta v_t r = \frac{4}{3}\pi r^3(\rho - \sigma)g$

$\Rightarrow v_t = Cr^2$ where C is a constant

or $v_t \propto r^2$

22. Ans. (C)

Explanation

$\because B = \frac{\Delta P}{(-\frac{\Delta V}{V})}$

$\Rightarrow \Delta P = 3 \times 10^{10} \times (0.02)$

$= 6 \times 10^8$ N/m^2

2021

Numerical

Q.1 A steel rod with $y = 2.0 \times 10^{11}$ Nm^{-2} and $\alpha\alpha = 10^{-5}$ $^{\circ\circ}C^{-1}$ of length 4 m and area of cross-section 10 cm^2 is heated from $0^{\circ\circ}C$ to $400^{\circ\circ}C$ without being allowed to extend. The tension produced in the rod is $x \times 10^5$ N where the value of x is ___________.

1st Sep Evening Shift 2021

Q.2 When a rubber ball is taken to a depth of _________m in deep sea, its volume decreases by 0.5%. (The bulk modulus of rubber = $9.8 \times\times 10^8$ Nm^{-2}, Density of sea water = 10^3 kgm^{-3}, g = 9.8 m/s^2)

31st Aug Morning Shift 2021

Q.3 Wires W_1 and W_2 are made of same material having the breaking stress of 1.25×10^9 N/m^2. W_1 and W_2 have cross-sectional area of 8×10^{-7} m^2 and 4×10^{-7} m^2, respectively. Masses of 20 kg and 10 kg hang from them as shown in the figure. The maximum mass that can be placed in the pan without breaking the wires is ___________ kg. (Use g = 10 m/s^2)

27st Aug Evening Shift 2021

Q.4 A soap bubble of radius 3 cm is formed inside the another soap bubble of radius 6 cm. The radius of an equivalent soap bubble which has the same excess pressure as inside the smaller bubble with respect to the atmospheric pressure is .... cm.

26st Aug Morning Shift 2021

Q.5 The water is filled upto height of 12 m in a tank having vertical sidewalls. A hole is made in one of the walls at a depth 'h' below the water level. The value of 'h' for which the emerging steam of water strikes the ground at the maximum range is _______ m.

27th July Evening Shift 2021

Q.6 A stone of mass 20 g is projected from a rubber catapult of length 0.1 m and area of cross section 10^{-6} m^2 stretched by an amount 0.04 m. The velocity of the projected stone is ____________ m/s.

(Young's modulus of rubber = 0.5×10^9 N/m^2)

27th July Morning Shift 2021

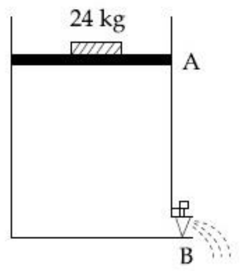
Q.7 The area of cross-section of a railway track is 0.01 m^2. The temperature variation is 10°C. Coefficient of liner expansion of material of track is $10^{-5}/^{\circ}$C. The energy stored per meter in the track is __________ J/m.

(Young's modulus of material of track is 10^{11} Nm^{-2})

22th July Evening Shift 2021

Q.8 Consider a water tank as shown in the figure. It's cross-sectional area is 0.4 m^2. The tank has an opening B near the bottom whose cross-section area is 1 cm^2. A load of 24 kg is applied on the water at the top when the height of the water level is 40 cm above the bottom, the velocity of water coming out the opening B is v ms^{-1}.

The value of v, to the nearest integer, is _________. [Take value of g to be 10 ms^{-2}]



18th Mar Evening Shift 2021

Q.9 Suppose you have taken a dilute solution of oleic acid in such a way that its concentration becomes 0.01 cm^3 of oleic acid per cm^3 of the solution. Then you make a thin film of this solution (monomolecular thickness) of area 4 cm^2 by considering 100 spherical drops of radius

$\left(\frac{3}{40\pi}\right)^{\frac{1}{3}} \times 10^{-3}$ Then the thickness of oleic acid layer will be x × 10^{-14} m. Where x is

__________.

17th Mar Evening Shift 2021

Q.10 A hydraulic press can lift 100 kg when a mass 'm' is placed on the smaller piston. It can lift __________ kg when the diameter of the larger piston is increased by 4 times and that of the smaller piston is decreased by 4 times keeping the same mass 'm' on the smaller piston.

24th Feb Morning Shift 2021

Numerical Answer Key

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1. **Ans. (8)**
2. **Ans. (500)**
3. **Ans. (40)**
4. **Ans. (2)**
5. **Ans. (6)**
6. **Ans. (20)**
7. **Ans. (05)**
8. **Ans. (3)**
9. **Ans. (25)**
10. **Ans. (25600)**

Numerical Explanation

Ans 1. Given, the Young's modulus of the steel rod, Y = 2 ×× 10^{11} Pa

Thermal coefficient of the steel rod, αα = 10^{-5}∘C

The length of the steel rod, l = 4 m

The area of the cross-section, A = 10 cm^2

The temperature difference, ΔT = 400◦C

As we know that,

Thermal strain = α ΔT

Using the Hooke's law

Young's modulus (Y) = $\frac{Thermal\ stress}{Thermal\ strain} = \frac{F/A}{\alpha\,\Delta\,T}$

Thermal stress, $F = YA\alpha\,\Delta T$

Substitute the values in the above equation, we get

$$F = 2 \times 10^{11} \times 10 \times 10^{-4} \times 10^{-5} \times (400)$$

$$= 8 \times 10^5 N$$

Comparing with, $F = x \times 10^5 N$

The value of the x = 8.

Ans 2.

$$B = -\frac{\Delta P}{\left(\frac{\Delta V}{V}\right)} = -\frac{\rho g h}{\left(\frac{\Delta V}{V}\right)}$$

$$-\frac{B\frac{\Delta V}{V}}{\rho g} = h$$

$$\frac{9.8 \times 10^8 \times 0.5}{100 \times 10^3 \times 9.8} = h$$

h = 500

Ans 3.

B.S$_1$ = $\frac{T_{1\,max}}{8\times10^{-7}}$ ⇒ T$_{1\ max}$ = 8 × 1.25 × 100 = 1000 N

B.S$_2$ = $\frac{T_{2\,max}}{4\times10^{-7}}$ ⇒ T$_{2\ max}$ = 4 × 1.25 × 100 = 500 N

m = $\frac{500-100}{10} = 40$ kg

Ans 4. Excess pressure inside the smaller soap bubble

$\Delta P = \frac{4S}{r_1} + \frac{4S}{r_2}$ .... (i)

The excess pressure inside equivalent soap bubble

$\Delta P = \frac{4S}{R_{eq}}$ .... (ii)

From (i) & (ii)

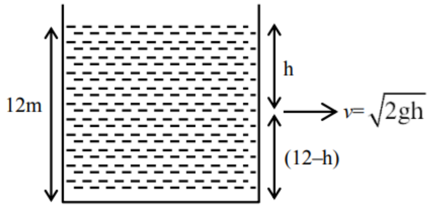
$$\frac{4S}{R_{eq}} = \frac{4S}{r_1} + \frac{4S}{r_2}$$

$$\frac{1}{R_{eq}} = \frac{1}{r_1} + \frac{1}{r_2}$$

$$= \frac{1}{6} + \frac{1}{3}$$

R$_{eq}$ = 2 cm

Ans 5.



$$R = \sqrt{2gh} \times \sqrt{\frac{(12-h)\times 2}{g}}$$

$$\sqrt{4h(12-h)} = R$$

For maximum R

$$\frac{dR}{dh} = 0$$

$\Rightarrow$ h = 6 m

Ans 6. By energy conservation

$$\frac{1}{2} \cdot \frac{YA}{L} \cdot x^2 = \frac{1}{2}mv^2$$

$$\frac{0.5\times10^9\times10^{-6}\times(0.04)^2}{0.1} = \frac{20}{1000}v^2$$

$$\therefore v^2 = 400$$

$v = 20$ m/s

Ans 7. As the tracks won't be allowed to expand linearly, the rise in temperature would lead to developing thermal stress in track.

$\frac{(Stress)}{y} = \alpha\Delta T$ or $\sigma = Y\alpha\Delta T$

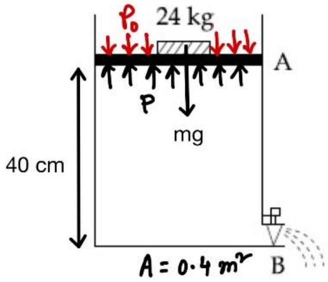
Energy stored per unit volume = $\frac{1}{2}\frac{\sigma}{Y}$

$\Rightarrow$ Energy stored per unit length = $\frac{A\sigma^2}{2Y}$

$$= \frac{A}{2} \times Y\alpha^2\Delta T^2$$

$= \frac{10^{-2}\times10^{11}\times10^{-10}\times100}{2} = 5$ J/m

Ans 8.



Force at point A,

$mg + p_0A = pA$

$$\Rightarrow p = p_0 + \frac{mg}{A}$$

Given, area of A = 0.4 m^2 = 0.4 × 10^4 cm^2 and area of B = 1 cm^2

applying continuity equation

$AV_1 = av$ [V_1 = velocity at point A]

$\Rightarrow V_1 = \frac{a}{A}v$

As A >>> a so $\frac{a}{A}$ very small

$\therefore V_1 <<< v$

So we can neglect V_1 by assuming $V_1 = 0$

On applying Bernoulli's theorem at points A and B,

$$p_0 + \frac{mg}{A} + \frac{\rho V_1^2}{2} + \rho gh = p_0 + \frac{\rho v^2}{2} + 0$$

$$\Rightarrow p_0 + \frac{mg}{A} + 0 + \rho gh = p_0 + \frac{\rho v^2}{2}$$

$$\Rightarrow \frac{mg}{A} + \rho gh = \frac{\rho v^2}{2}$$

$$\Rightarrow \frac{24 \times 10}{0.4} + 1000 \times 10 \times 0.4 = \frac{1000 \times v^2}{2}$$

$\Rightarrow v \simeq 3$ m/s

Ans 9.

$4t_T = 100 \times \frac{4}{3}\pi r^3$

$= 100 \times \frac{4}{3}\pi \times \frac{3}{40\pi} \times 10^{-9}$

$= 10^{-8}$ cm^3

$\Rightarrow t_T = 25 \times 10^{-10}$ cm

= 25×10^{-12} m

$t_0 = 0.01\, t_T = 25 \times 10^{-14}$ m

∴ x = 25

Ans 10. According to Pascal's law,

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Initially, $\frac{100g}{A_1} = \frac{mg}{A_2}$ .... (i)

Finally, $\frac{Mg}{16A_1} = \frac{mg}{\left(\frac{A_2}{16}\right)}$ ..... (ii)

On dividing Eqs. (i) by (ii), we get

$$\frac{100 \times 16}{M} = \frac{1}{16}$$

∴ M = 25600 kg

MCQ (Single Correct Answer)

Q.1 A bob of mass 'm' suspended by a thread of length l undergoes simple harmonic oscillations with time period T. If the bob is immersed in a liquid that has density $\frac{1}{4}$ times that of the bob and the length of the thread is increased by 1/3rd of the original length, then the time period of the simple harmonic oscillations will be:-

A T

B $\frac{3}{2}T$

C $\frac{3}{4}T$

D $\frac{4}{3}T$

31st Aug Evening Shift 2021

Q.2 Four identical hollow cylindrical columns of mild steel support a big structure of mass 50 ×× 10^3 kg. The inner and outer radii of each column are 50 cm and 100 cm respectively. Assuming uniform local distribution, calculate the compression strain of each column.

[Use Y = 2.0 ×× 10^{11} Pa, g = 9.8 m/s^2]

A 3.60×10^{-8}

B 2.60×10^{-7}

C 1.87×10^{-3}

D 7.07×10^{-4}

31st Aug Evening Shift 2021

Q.3 A uniform heavy rod of weight 10 kg ms^{-2}, cross-sectional area 100 cm^2 and length 20 cm is hanging from a fixed support. Young modulus of the material of the rod is 2 ×× 10^{11} Nm^{-2}. Neglecting the lateral contraction, find the elongation of rod due to its own weight.

Ⓐ 2×10^{-9} m

Ⓑ 5×10^{-8} m

Ⓒ 4×10^{-8} m

Ⓓ 5×10^{-10} m

31st Aug Morning Shift 2021

Q.4 In Millikan's oil drop experiment, what is viscous force acting on an uncharged drop of radius 2.0×10^{-5} m and density 1.2 ×× 10^{3} kgm^{-3} ? Take viscosity of liquid = 1.8 ×× 10^{-5} Nsm^{-2}. (Neglect buoyancy due to air).

Ⓐ 3.8×10^{-11} N

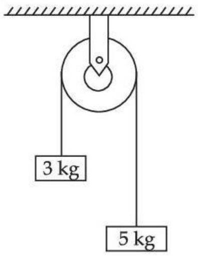
Ⓑ 3.9×10^{-10} N

Ⓒ 1.8×10^{-10} N

Ⓓ 5.8×10^{-10} N

27st Aug Morning Shift 2021

Q.5 Two blocks of masses 3 kg and 5 kg are connected by a metal wire going over a smooth pulley. The breaking stress of the metal is $\frac{24}{\pi} \times 10^2$ Nm^{-2}. What is the minimum radius of the wire ? (Take g = 10 ms^{-2})



A 125 cm

B 1250 cm

C 12.5 cm

D 1.25 cm

26st Aug Evening Shift 2021

Q.6 Two narrow bores of diameter 5.0 mm and 8.0 mm are joined together to form a U-shaped tube open at both ends. If this U-tube contains water, what is the difference in the level of two limbs of the tube. [Take surface tension of water T = 7.3×10^{-2} Nm^{-1}, angle of contact = 0, g = 10 ms^2 and density of water = 1.0 ×× 10^3 kg m^{-3}]

A 3.62 mm

B 2.19 mm

C 5.34 mm

D 4.97 mm

26st Aug Morning Shift 2021

Q.7 A raindrop with radius R = 0.2 mm falls from a cloud at a height h = 2000 m above the ground. Assume that the drop is spherical throughout its fall and the force of buoyancy may be neglected, then the terminal speed attained by the raindrop is:

[Density of water f_w = 1000 kg m^{-3} and Density of air f_a = 1.2 kg m^{-3}, g = 10 m/s^2, Coefficient of viscosity of air = 1.8×10^{-5} Nsm^{-2}]

A 250.6 ms^{-1}

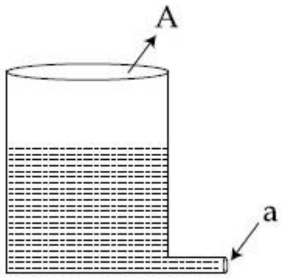
B 43.56 ms^{-1}

Ⓒ 4.94 ms^{-1}

Ⓓ 14.4 ms^{-1}

27th July Evening Shift 2021

Q.8 A light cylindrical vessel is kept on a horizontal surface. Area of base is A. A hole of cross-sectional area 'a' is made just at its bottom side. The minimum coefficient of friction necessary to prevent sliding the vessel due to the impact force of the emerging liquid is (a < < A) :



Ⓐ $\frac{A}{2a}$

Ⓑ None of these

Ⓒ $\frac{2a}{A}$

Ⓓ $\frac{a}{A}$

27th July Morning Shift 2021

Q.9 Two series of same length and radius are joined end to end and loaded. The Young's modulii of the materials of the two wires are Y_1 and Y_2. The combination behaves as a single wire then its Young's modulus is:

A $Y=\frac{2Y_1Y_2}{3(Y_1+Y_2)}$

B $Y=\frac{2Y_1Y_2}{Y_1+Y_2}$

C $Y=\frac{Y_1Y_2}{2(Y_1+Y_2)}$

D $Y=\frac{Y_1Y_2}{Y_1+Y_2}$

25th July Morning Shift 2021

Q. 10 Two small drops of mercury each of radius R coalesce to form a single large drop. The ratio of total surface energy before and after the change is :

A $2^{\frac{1}{3}}:1$

B $1:2^{\frac{1}{3}}$

C 2 : 1

D 1 : 2

20th July Evening Shift 2021

Q. 11 The value of tension in a long thin metal wire has been changed from T_1 to T_2. The lengths of the metal wire at two different values of tension T_1 and T_2 are l_1 and l_2 respectively. The actual length of the metal wire is :

A $\frac{l_1+l_2}{2}$

B $\sqrt{T_1T_2l_1l_2}$

C $\frac{T_1l_2-T_2l_1}{T_1-T_2}$

D $\frac{T_1l_1-T_2l_2}{T_1-T_2}$

20th July Morning Shift 2021

Q.12 An object is located at 2 km beneath the surface of the water. If the fractional compression $\frac{\Delta V}{V}$ is 1.36%, the ratio of hydraulic stress to the corresponding hydraulic strain will be __________. [Given : density of water is 1000 kgm^{-3} and g = 9.8 ms^{-2}]

Ⓐ $1.44 \times 10^7\ \mathrm{Nm}^{-2}$

Ⓑ $1.44 \times 10^9\ \mathrm{Nm}^{-2}$

Ⓒ $1.96 \times 10^7\ \mathrm{Nm}^{-2}$

Ⓓ $2.26 \times 10^9\ \mathrm{Nm}^{-2}$

17th Mar Evening Shift 2021

Q.13 When two soap bubbles of radii a and b (b > a) coalesce, the radius of curvature of common surface is :

Ⓐ $\frac{b-a}{ab}$

Ⓑ $\frac{a+b}{ab}$

Ⓒ $\frac{ab}{a+b}$

Ⓓ $\frac{ab}{b-a}$

17th Mar Morning Shift 2021

Q.14 What will be the nature of flow of water from a circular tap, when its flow rate increased from 0.18 L/min to 0.48 L/min? The radius of the tap and viscosity of water are 0.5 cm and 10^{-3} Pa s, respectively. (Density of water: 10^3 kg/m^3)

Ⓐ Steady flow to unsteady flow

Ⓑ Unsteady to steady flow

Ⓒ Remains turbulent flow

Ⓓ Remains steady flow

16th Mar Evening Shift 2021

Q.15 The pressure acting on a submarine is 3 × 10^5 Pa at a certain depth. If the depth is doubled, the percentage increase in the pressure acting on the submarine would be :

(Assume that atmospheric pressure is 1 × 10^5 Pa density of water is 10^3 kg m^{-3}, g = 10 ms^{-2})

Ⓐ $\frac{200}{5}\%$

Ⓑ $\frac{200}{3}\%$

Ⓒ $\frac{3}{200}\%$

Ⓓ $\frac{5}{200}\%$

16th Mar Morning Shift 2021

Q.16 The length of metallic wire is l_1 when tension in it is T_1. It is l_2 when the tension is T_2. The original length of the wire will be :

Ⓐ $\frac{T_1 l_1 - T_2 l_2}{T_2 - T_1}$

Ⓑ $\frac{l_1 + l_2}{2}$

Ⓒ $\frac{T_2 l_1 + T_1 l_2}{T_1 + T_2}$

Ⓓ $\frac{T_2 l_1 - T_1 l_2}{T_2 - T_1}$

26th Feb Evening Shift 2021

Q.17 The normal density of a material is ρ and its bulk modulus of elasticity is K. The magnitude of increase in density of material, when a pressure P is applied uniformly on all sides, will be :

A $\frac{\rho K}{P}$

B $\frac{PK}{\rho}$

C $\frac{\rho P}{K}$

D $\frac{K}{\rho P}$

26th Feb Morning Shift 2021

Q.18 A large number of water drops, each of radius r, combine to have a drop of radius R. If the surface tension is T and mechanical equivalent of heat is J, the rise in heat energy per unit volume will be:

A $\frac{2T}{J}\left(\frac{1}{r}-\frac{1}{R}\right)$

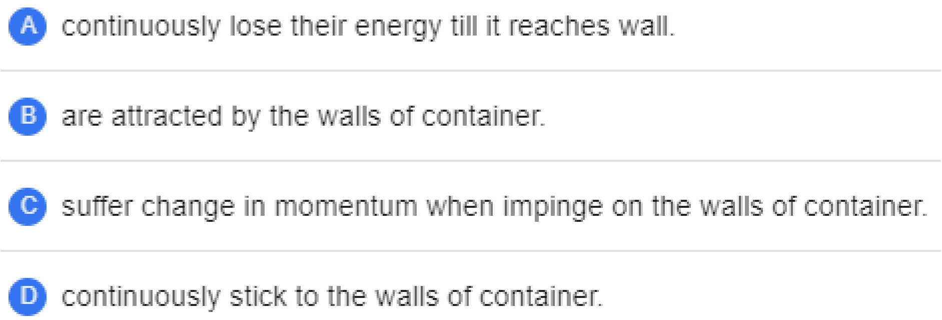
B $\frac{3T}{J}\left(\frac{1}{r}-\frac{1}{R}\right)$

C $\frac{3T}{rJ}$

D $\frac{2T}{rJ}$

26th Feb Morning Shift 2021

Q.19 On the basis of kinetic theory of gases, the gas exerts pressure because its molecules :



A continuously lose their energy till it reaches wall.

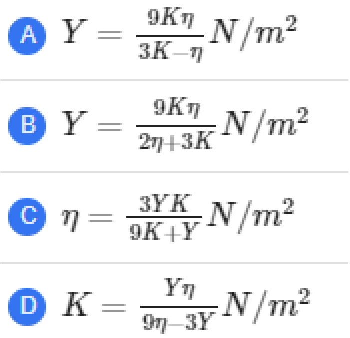
B are attracted by the walls of container.

C suffer change in momentum when impinge on the walls of container.

D continuously stick to the walls of container.

24th Feb Evening Shift 2021

Q.20 If Y, K and ηη are the values of Young's modulus, bulk modulus and modulus of rigidity of any material respectively. Choose the correct relation for these parameters.



A $Y=\frac{9K\eta}{3K-\eta}N/m^2$

B $Y=\frac{9K\eta}{2\eta+3K}N/m^2$

C $\eta=\frac{3YK}{9K+Y}N/m^2$

D $K=\frac{Y\eta}{9\eta-3Y}N/m^2$

24th Feb Morning Shift 2021

MCQ Answer Key

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1. Ans. (d)
2. Ans. (b)
3. Ans. (d)
4. Ans. (b)
5. Ans. (c)
6. Ans. (b)
7. Ans. (c)
8. Ans. (c)
9. Ans. (b)
10. Ans. (A)
11. Ans. (c)
12. Ans. (b)
13. Ans. (d)
14. Ans. (A)
15. Ans. (b)
16. Ans. (d)
17. Ans. (c)
18. Ans. (b)
19. Ans. (c)
20. Ans. (d)

MCQ Explanation

Ans 1.

$T = 2\pi\sqrt{l/g}$

When bob is immersed in liquid

mg_{eff} = mg − Buoyant force

mg_{eff} = mg − vσg (σ = density of liquid)

$= mg - v\frac{\rho}{4}g$

$= mg - \frac{mg}{4} = \frac{3mg}{4}$

$\therefore g_{eff} = \frac{3g}{4}$

$T_1 = 2\pi\sqrt{\frac{l_1}{g_{eff}}}$

$l_1 = l + \frac{l}{3} = \frac{4l}{3}, \, l_{eff} = \frac{3g}{4}$

By solving

$T_1 = \frac{4}{3}2\pi\sqrt{l/g}$

$T_1 = \frac{4T}{3}$

Ans 2.

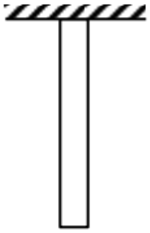
Force on each column = $\frac{mg}{4}$

Strain = $\frac{mg}{4AY}$

$$= \frac{50\times10^3\times9.8}{4\times\pi(1-0.25)\times2\times10^{11}}$$

= 2.6×10^{-7}

Ans 3.



We know,

$$\Delta l = \frac{WL}{2AY}$$

$$\Delta l = \frac{10\times1}{2\times5} \times 100 \times 10^{-4} \times 2 \times 10^{11}$$

$$\Delta l = \frac{1}{2} \times 10^{-9} = 5 \times 10^{-10} \text{ m}$$

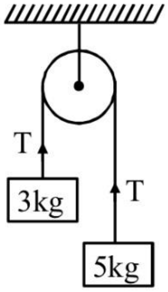
Option (d)

Ans 4. Viscous force = Weight

$$= \rho \times \left(\frac{4}{3}\pi r^3\right) g$$

= 3.9×10^{-10}

Ans 5.



$$T = \frac{2m_1m_2g}{m_1+m_2} = \frac{2\times3\times5\times10}{8}$$

$$= \frac{75}{2}$$

$$\text{Stress} = \frac{T}{A}$$

$$\frac{24}{\pi} \times 10^2 = \frac{75}{2\times\pi R^2}$$

$$R^2 = \frac{75}{2\times24\times100} = \frac{3}{8\times24}$$

⇒ R = 0.125 m

R = 12.5 cm

Ans 6. We have, $P_A = P_B$. [Points A & B at same horizontal level]

$$\therefore P_{atm} - \frac{2T}{r_1} + \rho g(x+\Delta h) = P_{atm} - \frac{2T}{r_2} + \rho gx$$

$$\therefore \rho g\Delta h = 2T\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

$$= 2\times7.3\times10^{-2}\left[\frac{1}{2.5\times10^{-3}} - \frac{1}{4\times10^{-3}}\right]$$

$$\therefore \Delta h = \frac{2\times7.3\times10^{-2}\times10^3}{10^3\times10}\left[\frac{1}{2.5} - \frac{1}{4}\right]$$

= 2.19 × 10^{-3} m = 2.19 mm

Hence, option (b).

Ans 7. At terminal speed

$a = 0$

$F_{net} = 0$

$mg = F_v = 6\pi\ \eta Rv$

$$v = \frac{mg}{6\pi\eta Rv}$$

$$v = \frac{\rho_w \frac{4\pi}{3} R^3 g}{6\pi\eta R}$$

$$= \frac{2\rho_w R^2 g}{9\eta}$$

$$= \frac{400}{81} \text{ m/s}$$

$= 4.94$ m/s

Ans 8. For no sliding

$f \geq \rho a v^2$

$\mu mg \geq \rho a v^2$

$\mu \rho Ahg \geq \rho a2gh$

$$\mu \geq \frac{2a}{A}$$

Ans 9.

In series combination $\Delta l = l_1 + l_2$

$$Y = \frac{F/A}{\Delta l/l} \Rightarrow \Delta l = \frac{Fl}{AY}$$

$$\Rightarrow \Delta l \propto \frac{l}{Y}$$

Equivalent length of rod after joining is = 2l

As, lengths are same and force is also same in series

$$\Delta l = \Delta l_1 + \Delta l_2$$

$$\frac{l_{eq}}{Y_{eq}} = \frac{l}{Y_1} + \frac{l}{Y_2} \Rightarrow \frac{2l}{Y} = \frac{l}{Y_1} + \frac{l}{Y_2}$$

$$\therefore Y = \frac{2Y_1Y_2}{Y_1+Y_2}$$

Ans 10.

$$\frac{4}{3}\pi R^3 + \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R'^3$$

$R' = 2^{\frac{1}{3}}R$ ..... (i)

$$A_i = 2[4\pi R^2]$$

$$A_f = 4\pi R'^2$$

$$\frac{U_i}{U_f} = \frac{A_i}{A_f} = \frac{2R^2}{2^{2/3}R^2} = 1^{1/3}$$

Ans 11. Suppose, I_0 be the actual length of metal wire and Y be its Young's modulus.

From Hooke's law,

$$Y = \frac{TI_0}{A\Delta I}$$

where, $\Delta I = I - I_0$

$$\Rightarrow Y = \frac{TI_0}{A(I - I_0)} \text{ or } I - I = \frac{TI_0}{AY}$$

$$\therefore \frac{I_1 - I_0}{I_2 - I_0} = \frac{T_1 I_0}{AY} \times \frac{AY}{T_2 I_0} = \frac{T_1}{T_2}$$

$$\Rightarrow I_1 T_2 - I_0 T_2 = I_2 T_1 - I_0 T_1$$

$$\Rightarrow I_0 = \frac{I_1 T_2 - I_2 T_1}{T_2 - T_1} = \frac{T_1 I_2 - T_2 I_1}{(T_1 - T_2)}$$

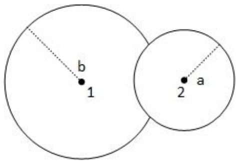
Ans 12.

$$\beta = \frac{\Delta p}{\frac{\Delta V}{V}}$$

$$\Rightarrow \beta = \frac{\Delta \rho g h}{\frac{\Delta V}{V}} = \frac{1000 \times 9.8 \times 2 \times 10^3}{\frac{1.36}{100}}$$

$\Rightarrow \beta = 1.44 \times 10^9$ N/m^2

Ans 13.



$P_1 - P_0 = \frac{4S}{b}$ ....(1)

$P_2 - P_0 - \frac{4S}{a}$ .....(2)

$P_2 - P_1 = \frac{4S}{R}$ ......(3)

eq(2) - eq(1) = eq(3)

$\Rightarrow \frac{1}{a} - \frac{1}{b} = \frac{1}{R}$

$\therefore R = \frac{ab}{b-a}$

Ans 14. The nature of flow is determined by reynolds no

$R = \frac{\rho VD}{\eta}$

If R < 1000 → flow is steady

1000 < R < 2000 → flow becomes unsteady

R > 2000 → flow is turbulent

$R_1 = \frac{4\times10^3\times0.18\times10^{-3}}{60\times\pi\times10^{-2}\times10^{-3}} = \frac{4\times10^5\times0.18}{60\pi}$

$= 0.0038 \times 10^5 = 380$

$R_2 = \frac{0.48}{0.18} \times 380 = 1018$

Ans 15.

P = P_0 + hρg = 3 × 10^5 Pa

⇒ hρg = 3 × 10^5 − 1 × 10^5

$\Rightarrow h\rho g = 2 \times 10^5$

$\therefore 2h\rho g = 4 \times 10^5$

$\therefore P' = P_0 + 4 \times 10^5$

$\therefore P' = 5 \times 10^5$ Pa

$\therefore$ % increase in pressure = $\frac{P'-P}{P} \times 100$

$= \frac{(5-3)\times10^5}{3\times10^5} \times 100$

$= \frac{200}{3}\%$

Ans 16. Assuming Hooke's law to be valid.

$T \propto (\Delta l)$

$T = k(\Delta l)$

Let, l_0 = natural length (original length)

$\Rightarrow T = k(l - l_0)$

so, $T_1 = k(l_1 - l_0)$ & $T_2 = k(l_2 - l_0)$

$\Rightarrow \frac{T_1}{T_2} = \frac{l_1-l_0}{l_2-l_0}$

$\Rightarrow l_0 = \frac{T_2 l_1 - T_1 l_2}{T_2 - T_1}$

Ans 17.

Bulk modulus $K = \frac{-\Delta P}{\frac{\Delta v}{v}} = \frac{-\Delta P v}{\Delta v}$

We know, $\rho = \frac{M}{V}$

So, $\frac{-\Delta \rho}{\rho} = \frac{\Delta v}{v}$

$$K = \frac{-\Delta P}{\left(-\frac{\Delta \rho}{\rho}\right)} = \frac{\rho \Delta P}{\Delta \rho}$$

$$\Delta \rho = \frac{\rho \Delta P}{K}$$

$$\Delta \rho = \frac{\rho P}{K}$$

Ans 18. R is the radius of bigger drop.

r is the radius of n water drops.

Water drops are combined to make bigger drop.

So,

Volume of n drops = volume of bigger drop

$$n\left(\frac{4}{3}\pi r^3\right) = \frac{4}{3}\pi R^3$$

$$\Rightarrow R = rn^{1/3} \Rightarrow n = \left(\frac{R}{r}\right)^3$$

Loss in surface energy, $\Delta U = T \times$ (Change in surface area)

$\Delta U = T\,(n4\pi r^2 - 4\pi R^2)$

$$\Delta U = 4\pi T\left[\left(\frac{R}{r}\right)^3 r^2 - R^2\right] = \frac{4\pi T\left(\frac{R^3}{r} - R^2\right)}{J}$$

$$\therefore \frac{\Delta U}{V} = \frac{4\pi T\left(\frac{R^3}{r} - R^2\right)}{J \times \frac{4}{3}\pi R^3} = \frac{3T}{J}\left[\frac{1}{r} - \frac{1}{R}\right]$$

Ans 19. On the basis of kinetic theory of gases, the gas exerts pressure because its molecules contain uniform speed, random motion and perform elastic collision with each other, as well as with the walls of container. As a result of which gaseous molecules suffer change in momentum when impinge on the walls of container

Ans 20. We know that,

$$Y = 3K(1 - 2\sigma)$$

$$\Rightarrow \sigma = \frac{1}{2}\left(1 - \frac{Y}{3K}\right) \text{ ..... (i)}$$

Also, $Y = 2\eta(1 + \sigma)$

$$\Rightarrow \sigma = \frac{Y}{2\eta} - 1 \text{ .... (ii)}$$

On comparing Eqs. (i) and (ii), we get

$$\left(1 - \frac{Y}{3K}\right)\frac{1}{2} = \frac{Y}{2\eta} - 1$$

On solving, we get

$$K = \frac{\eta Y}{9\eta - 3Y} \text{ N/m}^2$$

TOPIC 1 Thermometer & Thermal Expansion

1. Two different wires having lengths L_1 and L_2, and respective temperature coefficient of linear expansion α_1 and α_2, are joined end-to-end. Then the effective temperature coefficient of linear expansion is : **[Sep. 05, 2020 (II)]**

(a) $\frac{\alpha_1\ _1+\alpha_2\ _2}{L_1+L_2}$ (b) $2\sqrt{\alpha_1\alpha_2}$

(c) $\frac{\alpha_1+\alpha_2}{2}$ (d) $4\frac{\alpha_1\alpha_2}{\alpha_1+\alpha_2}\frac{L_2L_1}{(L_2+L_1)^2}$

2. A bakelite beaker has volume capacity of 500 cc at 30°C. When it is partially filled with V_m volume (at 30°C) of mercury, it is found that the unfilled volume of the beaker remains constant as temperature is varied. If $\gamma_{(\text{beaker})} = 6 \times 10^{-6}\ °C^{-1}$ and $\gamma_{(\text{mercury})} = 1.5 \times 10^{-4}\ °C^{-1}$, where γ is the coefficient of volume expansion, then V_m (in cc) is close to __________. **[NA Sep. 03, 2020 (I)]**

3. When the temperature of a metal wire is increased from 0°C to 10°C, its length increased by 0.02%. The percentage change in its mass density will be closest to : **[Sep. 02, 2020 (II)]**

(a) 0.06 (b) 2.3

(c) 0.008 (d) 0.8

4. A non-isotropic solid metal cube has coefficients of linear expansion as: 5×10^{-5}/°C along the x-axis and 5×10^{-6}/°C along the y and the z-axis. If the coefficient of volume expansion of the solid is $C \times 10^{-6}$/°C then the value of C is ______. **[NA 7 Jan. 2020 I]**

5. At 40°C, a brass wire of 1 mm radius is hung from the ceiling. A small mass, M is hung from the free end of the wire. When the wire is cooled down from 40°C to 20°C it regains its original length of 0.2 m. The value of M is close to: **[12 April 2019 I]**

(Coefficient of linear expansion and Young's modulus of brass are 10^{-5}/°C and 10^{11} N/m^2, respectively; $g = 10$ ms^{-2})

(a) 9 kg (b) 0.5 kg (c) 1.5 kg (d) 0.9 kg

6. Two rods A and B of identical dimensions are at temperature 30°C. If A is heated upto 180°C and B upto T°C, then the new lengths are the same. If the ratio of the coefficients of linear expansion of A and B is 4 : 3, then the value of T is : **[11 Jan. 2019 II]**

(a) 230°C (b) 270°C

(c) 200°C (d) 250°C

7. A thermometer graduated according to a linear scale reads a value x_0 when in contact with boiling water, and $x_0/3$ when in contact with ice. What is the temperature of an object in °C, if this thermometer in the contact with the object reads $x_0/2$? **[11 Jan. 2019 II]**

(a) 25 (b) 60 (c) 40 (d) 35

8. A rod, of length L at room temperature and uniform area of cross section A, is made of a metal having coefficient of linear expansion α/°C. It is observed that an external compressive force F, is applied on each of its ends, prevents any change in the length of the rod, when its temperature rises by ΔT K. Young's modulus, Y, for this metal is: **[9 Jan. 2019 I]**

(a) $\frac{F}{A\,\alpha\,\Delta T}$ (b) $\frac{F}{A\,\alpha\,(\Delta T - 273)}$

(c) $\frac{F}{2A\,\alpha\,\Delta T}$ (d) $\frac{2F}{A\,\alpha\,\Delta T}$

9. An external pressure P is applied on a cube at 0°C so that it is equally compressed from all sides. K is the bulk modulus of the material of the cube and α is its coefficient of linear expansion. Suppose we want to bring the cube to its original size by heating. The temperature should be raised by : **[2017]**

(a) $\frac{3\alpha}{PK}$ (b) $3PK\alpha$

(c) $\frac{P}{3\alpha}$ (d) $\frac{P}{\alpha}$

10. A steel rail of length 5 m and area of cross-section 40 cm^2 is prevented from expanding along its length while the temperature rises by 10°C. If coefficient of linear expansion and Young's modulus of steel are 1.2×10^{-5} K^{-1} and 2×10^{11} Nm^{-2} respectively, the force developed in the rail is approximately: **[Online April 9, 2017]**

(a) 2×10^7 N (b) 1×10^5 N

(c) 2×10^9 N (d) 3×10^{-5} N

11. A compressive force, F is applied at the two ends of a long thin steel rod. It is heated, simultaneously, such that its temperature increases by ΔT. The net change in its length is zero. Let l be the length of the rod, A its area of cross–section, Y its Young's modulus, and α its coefficient of linear expansion. Then, F is equal to : **[Online April 8, 2017]**

(a) $l^2 Y\alpha\Delta T$ (b) $lAY\alpha\Delta T$

(c) $AY\alpha\Delta T$ (d) $\dfrac{AY}{\alpha\Delta T}$

12. The ratio of the coefficient of volume expansion of a glass container to that of a viscous liquid kept inside the container is 1 : 4. What fraction of the inner volume of the container should the liquid occupy so that the volume of the remaining vacant space will be same at all temperatures ? **[Online April 23, 2013]**

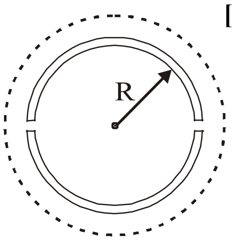
(a) 2 : 5 (b) 1 : 4 (c) 1 : 64 (d) 1 : 8

13. On a linear temperature scale Y, water freezes at – 160° Y and boils at – 50° Y. On this Y scale, a temperature of 340 K would be read as : (water freezes at 273 K and boils at 373 K) **[Online April 9, 2013]**

(a) – 73.7° Y (b) – 233.7° Y

(c) – 86.3° Y (d) – 106.3° Y

14. A wooden wheel of radius R is made of two semicircular part (see figure). The two parts are held together by a ring made of a metal strip of cross sectional area S and length L. L is slightly less than $2\pi R$. To fit the ring on the wheel, it is heated so that its temperature rises by ΔT and it just steps over the wheel. As it cools down to surrounding temperature, it presses the semicircular parts together. If the coefficient of linear expansion of the metal is α, and its Young's modulus is Y, the force that one part of the wheel applies on the other part is : **[2012]**



(a) $2\pi SY\alpha\Delta T$

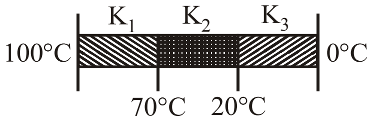
(b) $SY\alpha\Delta T$

(c) $\pi SY\alpha\Delta T$

(d) $2SY\alpha\Delta T$

TOPIC 2 Calorimetry and Heat Transfer

15. Three rods of identical cross-section and lengths are made of three different materials of thermal conductivity K_1, K_2 and K_3, respectively. They are joined together at their ends to make a long rod (see figure). One end of the long rod is maintained at 100ºC and the other at 0ºC (see figure). If the joints of the rod are at 70ºC and 20ºC in steady state and there is no loss of energy from the surface of the rod, the correct relationship between K_1, K_2 and K_3 is : **[Sep. 06, 2020 (II)]**



(a) $K_1 : K_3 = 2 : 3, K_1 < K_3 = 2 : 5$

(b) $K_1 < K_2 < K_3$

(c) $K_1 : K_2 = 5 : 2, K_1 : K_3 = 3 : 5$

(d) $K_1 > K_2 > K_3$

16. A bullet of mass 5 g, travelling with a speed of 210 m/s, strikes a fixed wooden target. One half of its kinetics energy is converted into heat in the bullet while the other half is converted into heat in the wood. The rise of temperature of the bullet if the specific heat of its material is 0.030 cal/(g – ºC) (1 cal = 4.2×10^7 ergs) close to : **[Sep. 05, 2020 (I)]**

(a) 87.5ºC (b) 83.3ºC

(c) 119.2ºC (d) 38.4ºC

17. The specific heat of water = 4200 J kg^{-1} K^{-1} and the latent heat of ice = 3.4×10^5 J kg^{-1}. 100 grams of ice at 0°C is placed in 200 g of water at 25°C. The amount of ice that will melt as the temperature of water reaches 0°C is close to (in grams) : **[Sep. 04, 2020 (I)]**

(a) 61.7 (b) 63.8

(c) 69.3 (d) 64.6

18. A calorimter of water equivalent 20 g contains 180 g of water at 25°C. 'm' grams of steam at 100°C is mixed in it till the temperature of the mixture is 31°C. The value of 'm' is close to (Latent heat of water = 540 cal g^{-1}, specific heat of water = 1 cal g^{-1} °C^{-1}) **[Sep. 03, 2020 (II)]**

(a) 2 (b) 4

(c) 3.2 (d) 2.6

19. Three containers C_1, C_2 and C_3 have water at different temperatures. The table below shows the final temperature T when different amounts of water (given in liters) are taken from each container and mixed (assume no loss of heat during the process) **[8 Jan. 2020 II]**

C_1	C_2	C_3	T
1 l	2 l	—	60°C
–	1 l	2 l	30°C
2 l	—	1 l	60°C
1 l	1 l	1 l	θ

The value of θ (in °C to the nearest integer) is______.

20. M grams of steam at 100°C is mixed with 200 g of ice at its melting point in a thermally insulated container. If it produces liquid water at 40°C [heat of vaporization of water is 540 cal/ g and heat of fusion of ice is 80 cal/g], the value of M is _________ **[NA 7 Jan. 2020 II]**

21. When M_1 gram of ice at –10 ºC (Specific heat = 0.5 cal g^{-1} ºC^{-1}) is added to M_2 gram of water at 50ºC, finally no ice is left and the water is at 0ºC. The value of latent heat of ice, in cal g^{-1} is: **[12 April 2019 I]**

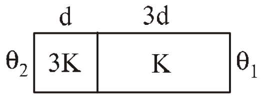
(a) $\frac{50M_2}{M_1}-5$ (b) $\frac{5M_1}{M_2}-50$

(c) $\frac{50M_2}{M_1}$ (d) $\frac{5M_2}{M_1}-5$

22. A massless spring (K = 800 N/m), attached with a mass (500 g) is completely immersed in 1kg of water. The spring is stretched by 2cm and released so that it starts vibrating. What would be the order of magnitude of the change in the temperature of water when the vibrations stop completely? (Assume that the water container and spring receive negligible heat and specific heat of mass = 400 J/kg K, specific heat of water = 4184 J/kg K) **[9 April 2019 II]**

(a) 10^{-4} K (b) 10^{-5} K (c) 10^{-1} K (d) 10^{-3} K

23. Two materials having coefficients of thermal conductivity '3*K*' and '*K*' and thickness '*d*' and '3*d*', respectively, are joined to form a slab as shown in the figure. The temperatures of the outer surfaces are 'θ_2' and 'θ_1' respectively, ($\theta_2 > \theta_1$). The temperature at the interface is: **[9 April 2019 II]**



(a) $\frac{\theta_1}{10}+\frac{9\theta_2}{10}$ (b) $\frac{\theta_2+\theta_1}{2}$

(c) $\frac{\theta_1}{6}+\frac{5\theta_2}{6}$ (d) $\frac{\theta_1}{3}+\frac{2\theta_2}{3}$

24. A cylinder of radius R is surrounded by a cylindrical shell of inner radius R and outer radius 2R. The thermal conductivity of the material of the inner cylinder is K_1 and that of the outer cylinder is K_2. Assuming no loss of heat, the effective thermal conductivity of the system for heat flowing along the length of the cylinder is: **[12 Jan. 2019 I]**

(a) $\frac{K_1+K_2}{2}$ (b) K_1+K_2

(c) $\frac{2K_1+3K_2}{5}$ (d) $\frac{K_1+3K_2}{4}$

25. Ice at –20°C is added to 50 g of water at 40°C, When the temperature of the mixture reaches 0°C, it is found that 20 g of ice is still unmelted. The amount of ice added to the water was close to **[11 Jan. 2019 I]**

(Specific heat of water = 4.2J/g/°C
Specific heat of Ice = 2.1 J/g/°C
Heat of fusion of water at 0°C = 334J/g)

(a) 50g (b) 100 g

(c) 60 g (d) 40 g

26. When 100 g of a liquid A at 100°C is added to 50 g of a liquid B at temperature 75°C, the temperature of the mixture becomes 90°C. The temperature of the mixture, if 100 g of liquid A at 100°C is added to 50 g of liquid B at 50°C, will be : **[11 Jan. 2019 II]**

(a) 85°C (b) 60°C

(c) 80°C (d) 70°C

27. A metal ball of mass 0.1 kg is heated upto 500°C and dropped into a vessel of heat capacity 800 JK^{-1} and containing 0.5 kg water. The initial temperature of water and vessel is 30°C. What is the approximate percentage increment in the temperature of the water? [Specific Heat Capacities of water and metal are, respectively, 4200 $Jkg^{-1}K^{-1}$ and 400 $Jkg^{-1}K^{-1}$] **[11 Jan. 2019 II]**

(a) 15% (b) 30%

(c) 25% (d) 20%

28. A heat source at T = 10^3 K is connected to another heat reservoir at T = 10^2 K by a copper slab which is 1 m thick. Given that the thermal conductivity of copper is 0.1 WK^{-1} m^{-1}, the energy flux through it in the steady state is: **[10 Jan. 2019 I]**

(a) 90 Wm^{-2} (b) 120 Wm^{-2}

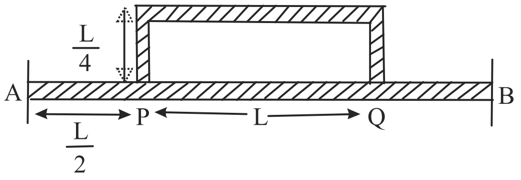
(c) 65 Wm^{-2} (d) 200 Wm^{-2}

29. An unknown metal of mass 192 g heated to a temperature of 100°C was immersed into a brass calorimeter of mass 128 g containing 240 g of water at a temperature of 8.4°C. Calculate the specific heat of the unknown metal if water temperature stablizes at 21.5°C. (Specific heat of brass is 394 J kg^{-1} K^{-1}) **[10 Jan. 2019 II]**

(a) 458 J kg^{-1} K^{-1} (b) 1232 J kg^{-1} K^{-1}

(c) 916 J kg^{-1} K^{-1} (d) 654 J kg^{-1} K^{-1}

30. Temperature difference of 120°C is maintained between two ends of a uniform rod AB of length 2L. Another bent rod PQ, of same cross-section as AB and length $\frac{3L}{2}$, is connected across AB (See figure). In steady state, temperature difference between P and Q will be close to: **[9 Jan. 2019 I]**



(a) 45°C (b) 75°C (c) 60°C (d) 35°C

31. A copper ball of mass 100 gm is at a temperature T. It is dropped in a copper calorimeter of mass 100 gm, filled with 170 gm of water at room temperature. Subsequently, the temperature of the system is found to be 75°C. T is given by (Given : room temperature = 30° C, specific heat of copper = 0.1 cal/gm°C **[2017]**

(a) 1250°C (b) 825°C (c) 800°C (d) 885° C

32. In an experiment a sphere of aluminium of mass 0.20 kg is heated upto 150°C. Immediately, it is put into water of volume 150 cc at 27°C kept in a calorimeter of water equivalent to 0.025 kg. Final temperature of the system is 40°C. The specific heat of aluminium is :
(take 4.2 Joule=1 calorie) **[Online April 8, 2017]**

(a) 378 J/kg – °C (b) 315 J/kg – °C

(c) 476 J/kg – °C (d) 434 J/kg – °C

33. An experiment takes 10 minutes to raise the temperature of water in a container from 0ºC to 100ºC and another 55 minutes to convert it totally into steam by a heater supplying heat at a uniform rate. Neglecting the specific heat of the container and taking specific heat of water to be 1 cal / g ºC, the heat of vapourization according to this experiment will come out to be : **[Online April 11, 2015]**

(a) 560 cal/ g (b) 550 cal/ g
(c) 540 cal/ g (d) 530 cal/ g

34. Three rods of Copper, Brass and Steel are welded together to form a Y shaped structure. Area of cross - section of each rod = 4 cm^2. End of copper rod is maintained at 100ºC where as ends of brass and steel are kept at 0ºC. Lengths of the copper, brass and steel rods are 46, 13 and 12 cms respectively. The rods are thermally insulated from surroundings excepts at ends. Thermal conductivities of copper, brass and steel are 0.92, 0.26 and 0.12 CGS units respectively. Rate of heat flow through copper rod is:**[2014]**

(a) 1.2 cal/s (b) 2.4 cal/s
(c) 4.8 cal/s (d) 6.0 cal/s

35. A black coloured solid sphere of radius R and mass M is inside a cavity with vacuum inside. The walls of the cavity are maintained at temperature T_0. The initial temperature of the sphere is $3T_0$. If the specific heat of the material of the sphere varies as αT^3 per unit mass with the temperature T of the sphere, where α is a constant, then the time taken for the sphere to cool down to temperature $2T_0$ will be (σ is Stefan Boltzmann constant) **[Online April 19, 2014]**

(a) $\frac{M\alpha}{4\pi R^2\sigma}\text{In}\left(\frac{3}{2}\right)$ (b) $\frac{M\alpha}{4\pi R^2\sigma}\text{In}\left(\frac{16}{3}\right)$

(c) $\frac{M\alpha}{16\pi R^2\sigma}\text{In}\left(\frac{16}{3}\right)$ (d) $\frac{M\alpha}{16\pi R^2\sigma}\text{In}\left(\frac{3}{2}\right)$

36. Water of volume 2 L in a closed container is heated with a coil of 1 kW. While water is heated, the container loses energy at a rate of 160 J/s. In how much time will the temperature of water rise from 27°C to 77°C? (Specific heat of water is 4.2 kJ/kg and that of the container is negligible). **[Online April 9, 2014]**

(a) 8 min 20 s (b) 6 min 2 s
(c) 7 min (d) 14 min

37. Assume that a drop of liquid evaporates by decrease in its surface energy, so that its temperature remains unchanged. What should be the minimum radius of the drop for this to be possible? The surface tension is T, density of liquid is ρ and L is its latent heat of vaporization. **[2013]**

(a) ρL/T (b) $\sqrt{T/\rho L}$ (c) T/ρL (d) 2T/ρL

38. A mass of 50g of water in a closed vessel, with surroundings at a constant temperature takes 2 minutes to cool from 30°C to 25°C. A mass of 100g of another liquid in an identical vessel with identical surroundings takes the same time to cool from 30° C to 25° C. The specific heat of the liquid is :

(The water equivalent of the vessel is 30g.)

[Online April 25, 2013]

(a) 2.0 kcal/kg (b) 7 kcal/kg
(c) 3 kcal/kg (d) 0.5 kcal/kg

39. 500 g of water and 100 g of ice at 0°C are in a calorimeter whose water equivalent is 40 g. 10 g of steam at 100°C is added to it. Then water in the calorimeter is : (Latent heat of ice = 80 cal/g, Latent heat of steam = 540 cal/ g) **[Online April 23, 2013]**

(a) 580 g (b) 590 g (c) 600 g (d) 610 g

40. Given that 1 g of water in liquid phase has volume 1 cm^3 and in vapour phase 1671 cm^3 at atmospheric pressure and the latent heat of vaporization of water is 2256 J/g; the change in the internal energy in joules for 1 g of water at 373 K when it changes from liquid phase to vapour phase at the same temperature is : **[Online April 22, 2013]**

(a) 2256 (b) 167 (c) 2089 (d) 1

41. A large cylindrical rod of length *L* is made by joining two identical rods of copper and steel of length $\left(\frac{L}{2}\right)$ each. The rods are completely insulated from the surroundings. If the free end of copper rod is maintained at 100°C and that of steel at 0°C then the temperature of junction is (Thermal conductivity of copper is 9 times that of steel) **[Online May 19, 2012]**

(a) 90ºC (b) 50ºC (c) 10ºC (d) 67ºC

42. The heat radiated per unit area in 1 hour by a furnace whose temperature is 3000 K is ($\sigma = 5.7 \times 10^{-8}$ W m^{-2} K^{-4}) **[Online May 7, 2012]**

(a) 1.7×10^{10} J (b) 1.1×10^{12} J
(c) 2.8×10^8 J (d) 4.6×10^6 J

43. 100g of water is heated from 30°C to 50°C. Ignoring the slight expansion of the water, the change in its internal energy is (specific heat of water is 4184 J/kg/K): **[2011]**

(a) 8.4 kJ (b) 84 kJ (c) 2.1 kJ (d) 4.2 kJ

44. The specific heat capacity of a metal at low temperature (T) is given as

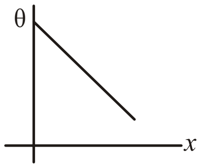
$$C_p(kJK^{-1}\text{kg}^{-1}) = 32\left(\frac{T}{400}\right)^3$$

A 100 gram vessel of this metal is to be cooled from 20ºK to 4ºK by a special refrigerator operating at room temperature (27°C). The amount of work required to cool the vessel is **[2011 RS]**

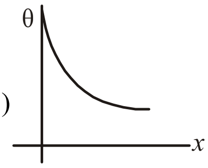
(a) greater than 0.148 kJ
(b) between 0.148 kJ and 0.028 kJ
(c) less than 0.028 kJ
(d) equal to 0.002 kJ

45. A long metallic bar is carrying heat from one of its ends to the other end under steady–state. The variation of temperature θ along the length x of the bar from its hot end is best described by which of the following figures? **[2009]**

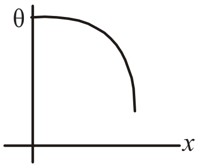
(a)



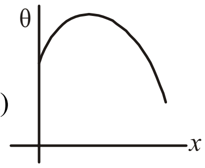
(b)



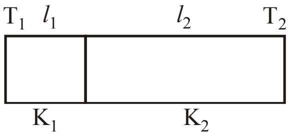
(c)



(d)



46. One end of a thermally insulated rod is kept at a temperature T_1 and the other at T_2. The rod is composed of two sections of length l_1 and l_2 and thermal conductivities K_1 and K_2 respectively. The temperature at the interface of the two section is **[2007]**



(a) $\dfrac{(K_1l_1T_1+K_2l_2T_2)}{(K_1l_1+K_2l_2)}$ (b) $\dfrac{(K_2l_2T_1+K_1l_1T_2)}{(K_1l_1+K_2l_2)}$

(c) $\dfrac{(K_2l_1T_1+K_1l_2T_2)}{(K_2l_1+K_1l_2)}$ (d) $\dfrac{(K_1l_2T_1+K_2l_1T_2)}{(K_1l_2+K_2l_1)}$

47. Assuming the Sun to be a spherical body of radius R at a temperature of TK, evaluate the total radiant powerd incident of Earth at a distance r from the Sun **[2006]**

(a) $4\pi r_0^2R^2\sigma\dfrac{T^4}{r^2}$ (b) $\pi r_0^2R^2\sigma\dfrac{T^4}{r^2}$

(c) $r_0^2R^2\sigma\dfrac{T^4}{4\pi r^2}$ (d) $R^2\sigma\dfrac{T^4}{r^2}$

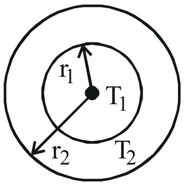
where r_0 is the radius of the Earth and σ is Stefan's constant.

48. Two rigid boxes containing different ideal gases are placed on a table. Box A contains one mole of nitrogen at temperature T_0, while Box contains one mole of helium at temperature $\left(\frac{7}{3}\right)T_0$. The boxes are then put into thermal contact with each other, and heat flows between them until the gases reach a common final temperature (ignore the heat capacity of boxes). Then, the final temperature of the gases, T_f in terms of T_0 is **[2006]**

(a) $T_f=\dfrac{3}{7}T_0$ (b) $T_f=\dfrac{7}{3}T_0$

(c) $T_f=\dfrac{3}{2}T_0$ (d) $T_f=\dfrac{5}{2}T_0$

49. The figure shows a system of two concentric spheres of radii r_1 and r_2 are kept at temperatures T_1 and T_2, respectively. The radial rate of flow of heat in a substance between the two concentric spheres is proportional to **[2005]**



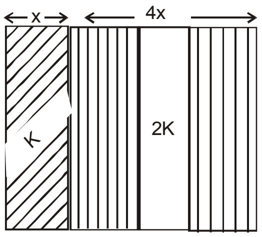
(a) $\ell n\left(\dfrac{r_2}{r_1}\right)$ (b) $\dfrac{(r_2-r_1)}{(r_1r_2)}$

(c) (r_2-r_1) (d) $\dfrac{r_1r_2}{(r_2-r_1)}$

50. If the temperature of the sun were to increase from T to $2T$ and its radius from R to $2R$, then the ratio of the radiant energy received on earth to what it was previously will be **[2004]**

(a) 32 (b) 16 (c) 4 (d) 64

51. The temperature of the two outer surfaces of a composite slab, consisting of two materials having coefficients of thermal conductivity K and $2K$ and thickness x and $4x$, respectively, are T_2 and $T_1(T_2>T_1)$. The rate of heat transfer through the slab, in a steady state is $\left(\dfrac{A(T_2-T_1)K}{x}\right)f$, with f equal to **[2004]**



(a) $\dfrac{2}{3}$ (b) $\dfrac{1}{2}$ (c) 1 (d) $\dfrac{1}{3}$

52. The earth radiates in the infra-red region of the spectrum. The spectrum is correctly given by **[2003]**

(a) Rayleigh Jeans law

(b) Planck's law of radiation

(c) Stefan's law of radiation

(d) Wien's law

53. Heat given to a body which raises its temperature by 1°C is **[2002]**

(a) water equivalent

(b) thermal capacity

(c) specific heat

(d) temperature gradient

54. Infrared radiation is detected by **[2002]**

(a) spectrometer (b) pyrometer

(c) nanometer (d) photometer

55. Which of the following is more close to a black body? **[2002]**

(a) black board paint (b) green leaves

(c) black holes (d) red roses

56. If mass-energy equivalence is taken into account, when water is cooled to form ice, the mass of water should **[2002]**

(a) increase

(b) remain unchanged

(c) decrease

(d) first increase then decrease

57. Two spheres of the same material have radii 1 m and 4 m and temperatures 4000 K and 2000 K respectively. The ratio of the energy radiated per second by the first sphere to that by the second is **[2002]**

(a) 1 : 1 (b) 16 : 1

(c) 4 : 1 (d) 1 : 9.

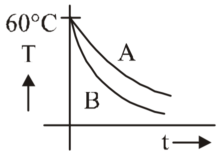
TOPIC 3 Newton's Law of Cooling

58. A metallic sphere cools from 50°C to 40°C in 300 s. If atmospheric temperature around is 20°C, then the sphere's temperature after the next 5 minutes will be close to : **[Sep. 03, 2020 (II)]**

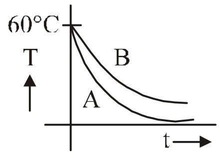
(a) 31°C (b) 33°C (c) 28°C (d) 35°C

59. Two identical beakers A and B contain equal volumes of two different liquids at 60°C each and left to cool down. Liquid in A has density of 8×10^2 kg/m^3 and specific heat of 2000 J kg^{-1} K^{-1} while liquid in B has density of 10^3 kg m^{-3} and specific heat of 4000 J kg^{-1} K^{-1}. Which of the following best describes their temperature versus time graph schematically ? (assume the emissivity of both the beakers to be the same) **[8 April 2019 I]**

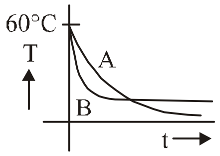
(a)



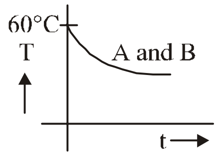
(b)



(c)



(d)



60. A body takes 10 minutes to cool from 60°C to 50°C. The temperature of surroundings is constant at 25°C. Then, the temperature of the body after next 10 minutes will be approximately **[Online April 15, 2018]**

(a) 43°C (b) 47°C (c) 41°C (d) 45°C

61. Hot water cools from 60°C to 50°C in the first 10 minutes and to 42°C in the next 10 minutes. The temperature of the surroundings is: **[Online April 12, 2014]**

(a) 25°C (b) 10°C (c) 15°C (d) 20°C

62. A hot body, obeying Newton's law of cooling is cooling down from its peak value 80°C to an ambient temperature of 30°C. It takes 5 minutes in cooling down from 80°C to 40°C. How much time will it take to cool down from 62°C to 32°C?

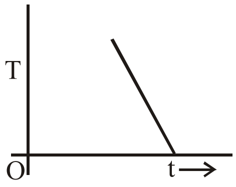
(Given In 2 = 0.693, In 5 = 1.609) **[Online April 11, 2014]**

(a) 3.75 minutes (b) 8.6 minutes

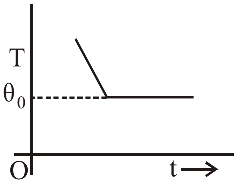
(c) 9.6 minutes (d) 6.5 minutes

63. If a piece of metal is heated to temperature θ and then allowed to cool in a room which is at temperature θ_0, the graph between the temperature T of the metal and time t will be closest to **[2013]**

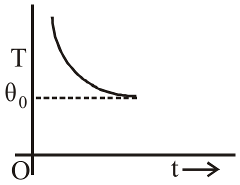
(a)



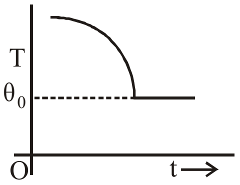
(b)



(c)

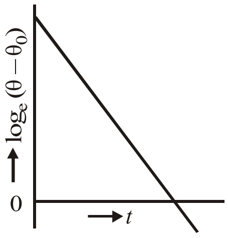


(d)

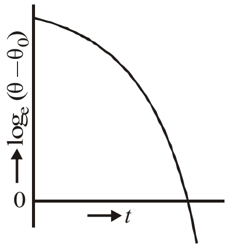


64. A liquid in a beaker has temperature θ(*t*) at time *t* and θ_0 is temperature of surroundings, then according to Newton's law of cooling the correct graph between $\log_e(\theta - \theta_0)$ and *t* is : **[2012]**

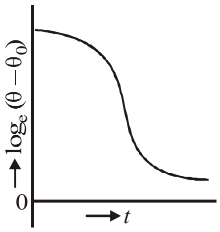
(a)



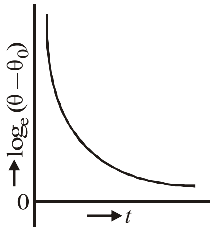
(b)



(c)



(d)



65. According to Newton's law of cooling, the rate of cooling of a body is proportional to $(\Delta\theta)^n$, where Δθ is the difference of the temperature of the body and the surroundings, and n is equal to **[2003]**

(a) two (b) three

(c) four (d) one

Hints & Solutions

1. **(a)** Let L_1' and L_2' be the lengths of the wire when temperature is changed by $\Delta T°\text{C}$.

At $T°\text{C}$,

$$L_{eq} = L_1 + L_2$$

At $T + \Delta°\text{C}$

$$L_{eq}' = L_1' + L_2'$$

$$\therefore \; L_{eq}(1+\alpha_{\text{eq}}\Delta T) = L_1(1+\alpha_1\Delta T) + L_2(1+\alpha_2\Delta T)$$

$$[\because L' = L(1+\alpha\Delta T)]$$

$$\Rightarrow (L_1+L_2)(1+\alpha_{\text{eq}}\Delta T) = L_1 + L_2 + L_1\alpha_1\Delta T + L_2\alpha_2\Delta T$$

$$\Rightarrow \alpha_{\text{eq}} = \frac{\alpha_1 L_1 + \alpha_2 L_2}{L_1 + L_2}$$

2. **(20.00)**

Volume capacity of beaker, $V_0 = 500$ cc

$$V_b = V_0 + V_0\gamma_{\text{beaker}}\Delta T$$

When beaker is partially filled with V_m volume of mercury,

$$V_b^1 = V_m + V_m\gamma_m\Delta T$$

Unfilled volume $(V_0 - V_m) = (V_b - V_m^1)$

$$\Rightarrow V_0\gamma_{\text{beaker}} = V_m\gamma_M$$

$$\therefore V_m = \frac{V_0\gamma_{\text{beaker}}}{\gamma_M}$$

$$\text{or, } V_m = \frac{500 \times 6 \times 10^{-6}}{1.5 \times 10^{-4}} = 20 \text{ cc.}$$

3. **(a)** Change in length of the metal wire (Δl) when its temperature is changed by ΔT is given by

$$\Delta l = l\alpha\Delta T$$

Here, α = Coefficient of linear expansion

Here, $\Delta l = 0.02\%$, $\Delta T = 10°\text{C}$

$$\therefore \alpha = \frac{\Delta l}{l\Delta T} = \frac{0.02}{100 \times 10}$$

$$\Rightarrow \alpha = 2 \times 10^{-5}$$

Volume coefficient of expansion, $\gamma = 3\alpha = 6 \times 10^{-5}$

$$\because \rho = \frac{M}{V}$$

$$\frac{\Delta V}{V} \times 100 = \gamma\Delta T = (6 \times 10^{-5} \times 10 \times 100) = 6 \times 10^{-2}$$

Volume increase by 0.06% therefore density decrease by 0.06%.

4. **(60.00)** Volume, $V = lbh$

$$\therefore \; \gamma = \frac{\Delta V}{V} = \frac{\Delta \ell}{\ell} + \frac{\Delta b}{b} + \frac{\Delta h}{h}$$

(γ = coefficient of volume expansion)

$$\Rightarrow \gamma = 5 \times 10^{-5} + 5 \times 10^{-6} + 5 \times 10^{-6}$$

$$= 60 \times 10^{-6}/°C$$

$\therefore$ Value of $C = 60.00$

5. **(Bonus)** $\Delta_{\text{temp}} = \Delta_{\text{load}}$ and $A = \pi r^2 = \pi(10^{-3})^2 = \pi \times 10^{-6}$

$$L\,\alpha\,\Delta T = \frac{FL}{AY}$$

$$\text{or} \quad 0.2 \times 10^{-5} \times 20 = \frac{F \times 0.2}{(\pi \times 10^{-6}) \times 10^{11}}$$

$$\therefore \quad F = 20\pi N \;\therefore m = \frac{f}{g} = 2\pi = 6.28 \text{ kg}$$

6. **(a)** Change in length in both rods are same i.e.

$$\Delta\ell_1 = \Delta\ell_2$$

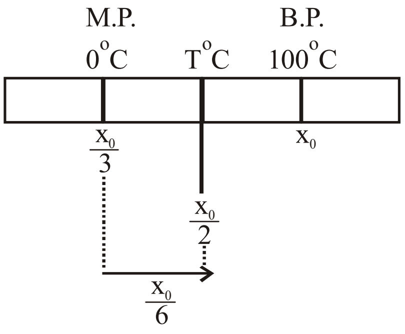
$$\ell\alpha_1\Delta\theta_1 = \ell\alpha_2\Delta\theta_2$$

$$\frac{\alpha_1}{\alpha_2} = \frac{\Delta\theta_2}{\Delta\theta_1} \qquad \left[\because \frac{\alpha_1}{\alpha_2} = \frac{4}{3}\right]$$

$$\frac{4}{3} = \frac{\theta - 30}{180 - 30}$$

$$\boxed{\theta = 230°\text{C}}$$

7. **(a)** Let required temperature = T°C



$$\Rightarrow T°\text{C} = \frac{x_0}{2} - \frac{x_0}{3} = \frac{x_0}{6}$$

$$\& \left(x_0 - \frac{x_0}{3}\right) = (100 - 0°\text{C})$$

$$\Rightarrow \frac{2x_0}{3} = 100 \Rightarrow x_0 = \frac{300}{2}$$

$$\Rightarrow T°C = \frac{x_0}{6} = \frac{150}{6} = 25°C$$

8. **(a)** Young's modulus $Y = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{A(\Delta\ell/\ell)}$

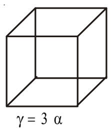
Using, coefficient of linear expansion,

$$\alpha = \frac{\Delta\ell}{\ell\Delta T} \Rightarrow \frac{\Delta\ell}{\ell} = \alpha\Delta T$$

$$\therefore Y = \frac{F}{A(\alpha\Delta T)}$$

9. **(c)** As we know, Bulk modulus

$$K = \frac{\Delta P}{\left(\frac{-\Delta V}{V}\right)} \quad \Rightarrow \frac{\Delta V}{V} = \frac{P}{K}$$



$$V = V_0(1 + \gamma\Delta t)$$

$$\frac{\Delta V}{V_0} = \gamma\Delta t$$

$$\therefore \quad \frac{P}{K} = \gamma\Delta t \Rightarrow \Delta t = \frac{P}{\gamma K} = \frac{P}{3\alpha K}$$

10. **(b)** Young's modulus $= \frac{\text{Thermal stress}}{\text{Strain}} = \frac{F/A}{\Delta L/L}$

$$Y = \frac{F}{A.\alpha.\Delta\theta} \qquad \left(\because \frac{\Delta L}{L} = \alpha\,\Delta\theta\right)$$

Force developed in the rail $F = YA\alpha\Delta t$

$= 2 \times 10^{11} \times 40 \times 10^{-4} \times 1.2 \times 10^{-5} \times 10$

$= 9.6 \times 10^4 = 1 \times 10^5$ N

11. **(c)** Due to thermal exp., change in length $(\Delta l) = l\,\alpha\,\Delta T$ ...(i)

Young's modulus (Y) $= \frac{\text{Normal stress}}{\text{Longitudinal strain}}$

$$Y = \frac{F/A}{\Delta l/l} \Rightarrow \frac{\Delta l}{l} = \frac{F}{AY}$$

$$\Delta l = \frac{Fl}{AY}$$

From eq^n (i), $\frac{Fl}{AY} = l\,\alpha\,\Delta T$

$F = AY\,\alpha\,\Delta T$

12. **(b)** When there is no change in liquid level in vessel then $\gamma'_{real} = \gamma'_{vessel}$

Change in volume in liquid relative to vessel

$$\Delta V_{app} = V\gamma'_{app}\,\Delta\theta = V(\gamma'_{real} - \gamma'_{vessel})$$

13. **(c)** $\frac{\text{Reading on any scale} - \text{LFP}}{\text{UFP} - \text{LFP}}$

= constant for all scales

$$\frac{340 - 273}{373 - 273} = \frac{°Y - (-160)}{-50 - (-160)}$$

$$\Rightarrow \frac{67}{100} = \frac{y + 160}{110}$$

$\therefore \quad Y = -86.3°\,Y$

14. **(d)** The Young modulus is given as

$$Y = \frac{\text{stress}}{\text{strain}} = \frac{F/S}{\Delta L/L}$$

Here, $\Delta L = 2\pi\,\Delta R\; L = 2\pi R$

$$Y = \frac{F}{S2\pi\Delta R} \times 2\pi R$$

$$\Rightarrow \quad Y = \frac{FR}{S.\Delta R} \qquad \text{...(i)}$$

The coefficient of linear expansion $\alpha = \frac{\Delta R}{R\Delta T}$

$$\Rightarrow \frac{\Delta R}{R} = \alpha.\Delta T \Rightarrow \frac{R}{\Delta R} = \frac{1}{\alpha\Delta T} \qquad \text{...(ii)}$$

From equation (i) and (ii)

$$Y = \frac{F}{S.\alpha\Delta T} \Rightarrow F = Y.S.\alpha\Delta T$$

$\therefore$ The ring is pressing the wheel from both sides, Thus

$F_{net} = 2F = 2YS\alpha\Delta T$

15. **(a)** As the rods are identical, so they have same length (l) and area of cross-section (A). They are connected in series. So, heat current will be same for all rods.

Heat current $= \left(\frac{\Delta Q}{\Delta t}\right)_{AB} = \left(\frac{\Delta Q}{\Delta t}\right)_{BC} = \left(\frac{\Delta Q}{\Delta t}\right)_{CD}$

$$\Rightarrow \frac{(100-70)K_1A}{l} = \frac{(70-20)K_2A}{l} = \frac{(20-0)K_3A}{l}$$

$$\Rightarrow K_1(100-70) = K_2(70-20) = K_3(20-0)$$

$$\Rightarrow K_1(30) = K_2(50) = K_3(20)$$

$$\Rightarrow \frac{K_1}{10} = \frac{K_2}{6} = \frac{K_3}{15}$$

$$\Rightarrow K_1 : K_2 : K_3 = 10 : 6 : 15$$

$$\Rightarrow K_1 : K_3 = 2 : 3.$$

16. **(a)** According to question, one half of its kinetic energy is converted into heat in the wood.

$$\frac{1}{2}mv^2 \times \frac{1}{2} = ms\Delta T$$

$$\Rightarrow \Delta T = \frac{v^2}{4 \times s} = \frac{210 \times 210}{4 \times 4.2 \times 0.3 \times 1000} = 87.5°C$$

17. **(a)** Here ice melts due to water.

Let the amount of ice melts $= m_{ice}$

$$m_w s_w \Delta\theta = m_{ice} L_{ice}$$

$$\therefore m_{\text{ice}} = \frac{m_w s_w \Delta\theta}{L_{\text{ice}}}$$

$$= \frac{0.2 \times 4200 \times 25}{3.4 \times 10^5} = 0.0617 \text{ kg} = 61.7 \text{ g}$$

18. **(a)** Heat given by water $= m_w C_w (T_{\text{mix}} - T_w)$

$$= 200 \times 1 \times (31 - 25)$$

Heat taken by steam $= m\,L_{\text{stem}} + m\,C_w\,(T_s - T_{\text{mix}})$

$= \text{m} \times 540 + \text{m}\,(1) \times (100 – 31)$

$= \text{m} \times 540 + \text{m}\,(1) \times (69)$

From the principal of calorimeter,

Heat lost = Heat gained

$\therefore (200)(31 - 25) = m \times 540 + m(1)(69)$

$\Rightarrow 1200 = m(609) \Rightarrow m \approx 2.$

19. **(50.00)**

Let Q_1, Q_2, Q_3 be the temperatures of container C_1, C_2 and C_3 respectively.

Using principle of calorimetry in container C_1, we have

$(\theta_1 - 60) = 2\,\text{ms}(60 - \theta)$

$\Rightarrow \theta_1 - 60 = 120 - 2\theta$

$\Rightarrow \theta_1 = 180 - 2\theta$ ...(i)

For container C_2

$\text{ms}\,(\theta_2 - 30) = 2\text{ms}\,(30 - \theta)$

$\Rightarrow \theta_2 = 90 - 2\theta3$ ...(ii)

For container C_3

$2\text{ms}\,(\theta_1 - 60) = \text{ms}\,(60 - \theta)$

$\Rightarrow 2\theta_1 – 120 = 60 - \theta$

$\Rightarrow 2\theta_1 + \theta = 180$ ...(iii)

Also, $\theta_1 + \theta_2 + \theta_3 = 3\theta$ ...(iv)

Adding (i), (ii) and (iii)

$3\theta_1 + 3\theta_2 + 3\theta_3 = 450$

$\Rightarrow \quad \theta_1 + \theta_2 + \theta_3 = 150$

$\Rightarrow \quad 3\theta = 150 \quad \Rightarrow \quad \theta = 50\,°\text{C}$

20. **(40)** Using the principal of calorimetry

$M_{\text{ice}}\,L_f + m_{\text{ice}}\,(40 - 0)\,C_w$

$= m_{\text{stream}}\,L_v + m_{\text{stream}}\,(100 - 40)\,C_w$

$\Rightarrow M\,(540) + M \times 1 \times (100 - 40)$

$= 200 \times 80 + 200 \times 1 \times 40$

$\Rightarrow 600\,M = 24000$

$\Rightarrow M = 40g$

21. **(a)** $M_1 C_{\text{ice}} \times (10) + M_1 L = M_2 C_\omega\,(50)$

or $M_1 \times C_{ice}\,(=0.5) \times 10 + M_1 L = M_2 \times 1 \times 50$

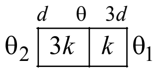
$$\Rightarrow \text{L} = \frac{50M_2}{M_1} - 5$$

22. **(b)** $\frac{1}{2}.kx^2 = mC(\Delta T) + m_\omega C_\omega \Delta T$

or $\frac{1}{2} \times 800 \times 0.02^2 = 0.5 \times 400 \times \Delta T + 1 \times 4184 \times \Delta T$

$\therefore \Delta T = 1 \times 10^{-5} K$

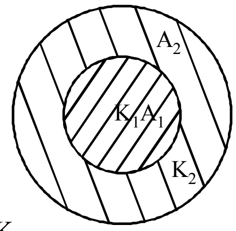
23. **(a)** $H_1 = H_2$



or $(3k)A\left(\frac{\theta_2 - \theta}{d}\right) = kA\left(\frac{\theta - \theta_1}{3d}\right)$

or $\theta = \left(\frac{\theta_1 + 9\theta_2}{10}\right)$

24. **(d)** Effective thermal conductivity of system



$$\text{K}_{\text{eq}} = \frac{\text{K}_1\text{A}_1 + \text{K}_2\text{A}_2}{\text{A}_1 + \text{A}_2}$$

$$= \frac{\text{K}_1\pi\text{R}^2 + \text{K}_2[\pi(2\text{R})^2 - \pi\text{R}^2]}{\pi(2\text{R})^2}$$

$$= \frac{\text{K}_1(\pi\text{R}^2) + \text{K}_2(3\pi\text{R}^2)}{4\pi\text{R}^2} = \frac{\text{K}_1 + 3\text{K}_2}{4}$$

25. **(d)** Let m gram of ice is added.

From principal of calorimeter

heat gained (by ice) = heat lost (by water)

$\therefore\; 20 \times 2.1 \times \text{m} + (\text{m} - 20) \times 334$

$= 50 \times 4.2 \times 40$

$376\,\text{m} = 8400 + 6680$

$\text{m} = 40.1$

26. **(c)** Heat loss = Heat gain = $\text{mS}\Delta\theta$

So, $\text{m}_\text{A}\text{S}_\text{A}\Delta\theta_\text{A} = \text{m}_\text{B}\text{S}_\text{B}\Delta\theta_\text{B}$

$\Rightarrow 100 \times \text{S}_\text{A} \times (100 - 90) = 50 \times \text{S}_\text{B} \times (90 - 75)$

$2\text{S}_\text{A} = 1.5\text{S}_\text{B} \Rightarrow \text{S}_\text{A} = \frac{3}{4}\text{S}_\text{B}$

Now, $100 \times \text{S}_\text{A} \times (100 - \theta) = 50 \times \text{S}_\text{B} \times (\theta - 50)$

$2 \times \left(\frac{3}{4}\right) \times (100 - \theta) = (\theta - 50)$

$300 - 3\theta = 2\theta - 100$

$400 = 5\theta \Rightarrow \theta = 80°\text{C}$

27. **(d)** Assume final temperature = T°C

Heat lass = Heat gain = $\text{ms}\Delta\text{T}$

$\Rightarrow \text{m}_\text{B}\,\text{s}_\text{B}\,\Delta\text{T}_\text{B} = \text{m}_\text{w}\,\text{s}_\text{w}\Delta\text{T}_\text{w}$

$0.1 \times 400 \times (500 - \text{T})$

$= 0.5 \times 4200 \times (\text{T} - 30) + 800\,(\text{T} - 30)$

$\Rightarrow 40\,(500 - \text{T}) = (\text{T} - 30)\,(2100 + 800)$

$\Rightarrow 20000 - 40\text{T} = 2900\,\text{T} – 30 \times 2900$

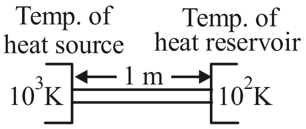
$\Rightarrow 20000 + 30 \times 2900 = \text{T}(2940)$

$\text{T} = 30.4°\text{C}$

$$\frac{\Delta T}{T}\times 100=\frac{6.4}{30}\times 100=21\%,$$

so the closest answer is 20%.

28. (a)



$$\left(\frac{dQ}{dt}\right)=\frac{k A \Delta T}{\ell}$$

$$\text{Energy flux, } \frac{1}{A}\left(\frac{dQ}{dt}\right)=\frac{k\Delta T}{\ell}$$

$$=\frac{(0.1)(900)}{1}=90\ \text{W/m}^2$$

29. (c) Let specific heat of unknown metal be 's' According to principle of calorimetry, Heat lost

$= \text{Heat gain } m \times s\Delta\theta = m_1 s_{brass}(\Delta\theta_1 + m_2 s_{water} + \Delta\theta_2)$

$\Rightarrow 192 \times S \times (100-21.5)$

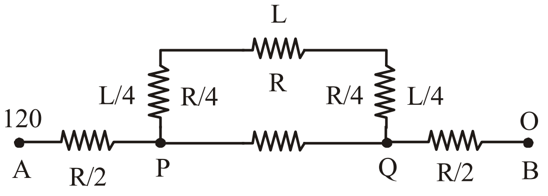
$= 128 \times 394 \times (21.5-8.4)$

Solving we get,$+ 240 \times 4200 \times (21.5-8.4)$

$S = 916\ \text{Jkg}^{-1}\text{k}^{-1}$

30. (a)

$$\frac{\Delta T_{AB}}{R_{AB}}=\frac{120}{\frac{8}{5}R}=\frac{120\times 5}{8R}$$



In steady state temperature difference between P and Q,

$$\Delta T_{PQ}=\frac{120\times 5}{8R}\times\frac{3}{5}R=\frac{360}{8}=45°C$$

31. (d) According to principle of calorimetry,

Heat lost = Heat gain

$100 \times 0.1(T-75) = 100 \times 0.1 \times 45 + 170 \times 1 \times 45$

$10\,T - 750 = 450 + 7650 = 8100$

$\Rightarrow T - 75 = 810$

$T = 885°C$

32. (d) According to principle of calorimetry,

$Q_{given} = Q_{used}$

$0.2 \times S \times (150-40) = 150 \times 1 \times (40-27) + 25 \times (40-27)$

$0.2 \times S \times 110 = 150 \times 13 + 25 \times 13$

Specific heat of aluminium

$$S=\frac{13\times 25\times 7}{0.2\times 110}=434\ \text{J/kg-°C}$$

33. (b) As $Pt = mC\Delta T$

So, $P \times 10 \times 60 = mC\ 100$ ...(i)

and $P \times 55 \times 60 = mL$ ...(ii)

Dividing equation (i) by (ii) we get

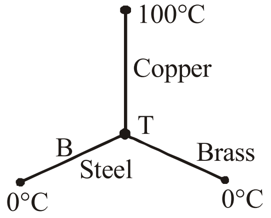
$$\frac{10}{55}=\frac{C\times 100}{L}$$

$\therefore L = 550$ cal./g.

34. (c) Rate of heat flow is given by,

$$Q=\frac{KA(\theta_1-\theta_2)}{l}$$

Where, K = coefficient of thermal conductivity
l = length of rod and A = area of cross-section of rod



If the junction temperature is T, then

$Q_{Copper} = Q_{Brass} + Q_{Steel}$

$$\frac{0.92\times 4(100-T)}{46}$$

$$=\frac{0.26\times 4\times (T-0)}{13}+\frac{0.12\times 4\times (T-0)}{12}$$

$\Rightarrow\ 200 - 2T = 2T + T$

$\Rightarrow\ T = 40°C$

$$\therefore\quad Q_{Copper}=\frac{0.92\times 4\times 60}{46}=4.8\ \text{cal/s}$$

35. (c) In the given problem, fall in temperature of sphere,

$dT = (3T_0 - 2T_0) = T_0$

Temperature of surrounding, $T_{surr} = T_0$

Initial temperature of sphere, $T_{initial} = 3T_0$

Specific heat of the material of the sphere varies as,

$c = \alpha T^3$ per unit mass (α = a constant)

Applying formula,

$$\frac{dT}{dt}=\frac{\sigma A}{McJ}\left(T^4-T_{surr}^4\right)$$

$$\Rightarrow \frac{T_0}{dt}=\frac{\sigma 4\pi R^2}{M\alpha(3T_0)^3 J}\left[(3T_0)^4-(T_0)^4\right]$$

$$\Rightarrow dt=\frac{M\alpha 27T_0^4 J}{\sigma 4\pi R^2\times 80T_0^4}$$

Solving we get,

Time taken for the sphere to cool down temperature $2T_0$,

$$t=\frac{M\alpha}{16\pi R^2\sigma}\ln\left(\frac{16}{3}\right)$$

36. **(a)** From question,

In 1 sec heat gained by water

= 1 KW – 160 J/s

= 1000 J/s – 160 J/s

= 840 J/s

Total heat required to raise the temperature of water (volume 2L) from 27°c to 77°c

$= m_{water} \times sp.\ ht \times \Delta\theta$

$= 2 \times 10^3 \times 4.2 \times 50$ [$\because$ mass = density × volume]

And, $840 \times t = 2 \times 10^3 \times 4.2 \times 50$

$$\text{or,}\quad t = \frac{2\times10^3\times4.2\times50}{840}$$

= 500 s = 8 min 20s

37. **(d)** When radius is decrease by ΔR,

$$4\pi R^2 \Delta R \rho L = 4\pi T[R^2 - (R - \Delta R)^2]$$

$$\Rightarrow \rho R^2 \Delta RL = T[R^2 - R^2 + 2R\Delta R - \Delta R^2]$$

$$\Rightarrow \rho R^2 \Delta RL = T2R\Delta R \qquad [\Delta R \text{ is very small}]$$

$$\Rightarrow R = \frac{2T}{\rho L}$$

38. **(d)** As the surrounding is identical, vessel is identical time taken to cool both water and liquid (from 30°C to 25°C) is same 2 minutes, therefore

$$\left(\frac{dQ}{dt}\right)_{water} = \left(\frac{dQ}{dt}\right)_{liquid}$$

$$\text{or,}\quad \frac{(m_W C_W + W)\Delta T}{t} = \frac{(m_\ell C_\ell + W)\Delta T}{t}$$

(W = water equivalent of the vessel)

$$\text{or},\ m_W C_W = m_\ell C_\ell$$

$$\therefore \text{ Specific heat of liquid},\ C_\ell = \frac{m_W C_W}{m_\ell}$$

$$= \frac{50\times1}{100} = 0.5\ \text{kcal / kg}$$

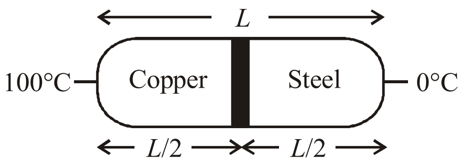
39. **(b)** As 1g of steam at 100°C melts 8g of ice at 0°C.

10 g of steam will melt 8× 10 g of ice at 0°C

Water in calorimeter = 500 + 80 + 10g = 590g

40. **(c)**

41. **(a)**



Let conductivity of steel $K_{steel} = k$ then from question Conductivity of copper $K_{copper} = 9k$

$\theta_{copper} = 100°C$

$\theta_{steel} = 0°C$

$$l_{steel} = l_{copper} = \frac{L}{2}$$

From formula temperature of junction;

$$\theta = \frac{K_{copper}\theta_{copper}\, l_{steel} + K_{steel}\,\theta_{steel}\, l_{copper}}{K_{copper}\, l_{steel} + K_{steel}\, l_{copper}}$$

$$= \frac{9k\times100\times\frac{L}{2} + k\times0\times\frac{L}{2}}{9k\times\frac{L}{2} + k\times\frac{L}{2}}$$

$$= \frac{\frac{900}{2}kL}{\frac{10kL}{2}} = 90°C$$

42. **(a)** According to Stefan's law

$E = \sigma T^4$

Heat radiated per unit area in 1 hour (3600s) is

$= 5.7\times 10^{-8} \times (300)^4 \times 3600 = 1.7 \times 10^{10}$ J

43. **(a)** $\Delta U = \Delta Q = mc\Delta T$

$$= \frac{100}{1000} \times 4184\,(50-30) \approx 8.4\ \text{kJ}$$

44. **(d)** Required work = energy released

$$\text{Here, } Q = \int mc\,dT$$

$$= \int_{20}^{4} 0.1\times32\times\left(\frac{T^3}{400^3}\right) dT = \int_{20}^{4} \frac{3.2}{64\times10^6} T^3 dT$$

$$= 5\times10^{-8}\int_{20}^{4} T^3 dT = 0.002kJ$$

Therefore, required work = 0.002 kJ

45. **(a)** Let Q be the temperature at a distance x from hot end of bar. Let Q is the temperature of hot end.

The heat flow rate is given by

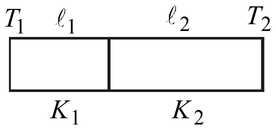
$$\frac{dQ}{dt} = \frac{kA(\theta_1 - \theta)}{x}$$

$$\Rightarrow \theta_1 - \theta = \frac{x}{kA}\frac{dQ}{dt} \qquad \Rightarrow \theta = \theta_1 - \frac{x}{kA}\frac{dQ}{dt}$$

Thus, the graph of Q versus x is a straight line with a positive intercept and a negative slope.

The above equation can be graphically represented by option (a).

46. **(d)** Let T be the temperature of the interface. In the steady state, $Q_1 = Q_2$



$$\therefore \frac{K_1 A(T_1 - T)}{\ell_1} = \frac{K_2 A(T - T_2)}{\ell_2},$$

where A is the area of cross-section.

$$\Rightarrow \quad K_1A(T_1-T)\ell_2 = K_2A(T-T_2)\ell_1$$

$$\Rightarrow \quad K_1T_1\ell_2 - K_1T\ell_2 = K_2T\ell_1 - K_2T_2\ell_1$$

$$\Rightarrow \quad (K_2\ell_1 + K_1\ell_2)T = K_1T_1\ell_2 + K_2T_2\ell_1$$

$$\Rightarrow \quad T = \frac{K_1T_1\ell_2 + K_2T_2\ell_1}{K_2\ell_1 + K_1\ell_2}$$

$$= \frac{K_1\ell_2T_1 + K_2\ell_1T_2}{K_1\ell_2 + K_2\ell_1}.$$

47. **(b)** From stefan's law, total power radiated by Sun, $E = \sigma T^4 \times 4\pi R^2$

The intensity of power Per unit area incident on earth's surface

$$= \frac{\sigma T^4 \times 4\pi R^2}{4\pi r^2}$$

Total power received by Earth

$$E' = \frac{E}{4\pi r^2} \times \text{Cross – Section area of earth facing the}$$

$$\text{sun} = \frac{\sigma T^4 R^2}{r^2}(\pi r_0^2)$$

48. **(c)** When two gases are mixed to gether then

Heat lost by He gas = Heat gained by N_2 gas

$$n_1C_{v_1}\Delta T_1 = n_2C_{v_2}\Delta T_2$$

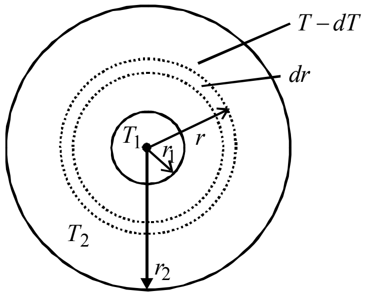
$$\frac{3}{2}R\left[\frac{7}{3}T_0 - T_f\right] = \frac{5}{2}R\left[T_f - T_0\right]$$

$$7T_0 - 3T_f = 5T_f - 5T_0$$

$$\Rightarrow 12T_0 = 8T_f \Rightarrow T_f = \frac{12}{8}T_0$$

$$\Rightarrow T_f = \frac{3}{2}T_0\,..$$

49. **(d)**



Consider a thin concentric shell of thickness (*dr*) and of radius (*r*) and let the temperature of inner and outer surfaces of this shell be *T* and (*T* – *dT*) respectively.

The radial rate of flow of heat through this elementary shell will be

$$\frac{dQ}{dt} = \frac{KA[(T-dT)-T]}{dr} = \frac{-KAdT}{dr}$$

$$= -4\pi Kr^2\frac{dT}{dr} \qquad (\because\ A = 4\pi r^2)$$

Since the area of the surface through which heat will flow is not constant. Integrating both sides between the limits of radii and temperatures of the two shells, we get

$$\left(\frac{dQ}{dt}\right)\int_{r_1}^{r_2}\frac{1}{r^2}dr = -4\pi K\int_{T_1}^{T_2}dT$$

$$\left(\frac{dQ}{dt}\right)\int_{r_1}^{r_2}r^{-2}dr = -4\pi K\int_{T_1}^{T_2}dT$$

$$\frac{dQ}{dt}\left[\frac{1}{r_1}-\frac{1}{r_2}\right] = -4\pi K\left[T_2 - T_1\right]$$

$$\text{or} \quad \frac{dQ}{dt} = \frac{-4\pi Kr_1r_2(T_2-T_1)}{(r_2-r_1)}$$

$$\therefore \quad \frac{dQ}{dt} \propto \frac{r_1\,r_2}{(r_2-r_1)}$$

50. **(d)** From stefan's law, energy radiated by sun per second

$$E = \sigma AT^4;$$

$$\therefore A \propto R^2$$

$$\therefore E \propto R^2T^4$$

$$\therefore \frac{E_2}{E_1} = \frac{R_2^2\,T_2^4}{R_1^2\,T_1^4}$$

put $R_2 = 2R$, $R_1 = R$; $T_2 = 2T$, $T_1 = T$

$$\Rightarrow \frac{E_2}{E_1} = \frac{(2R)^2(2T)^4}{R^2T^4} = 64$$

51. **(d)** The thermal resistance is given by

$$\frac{x}{KA} + \frac{4x}{2KA} = \frac{x}{KA} + \frac{2x}{KA} = \frac{3x}{KA}$$

Amount of heat flow per second,

$$\frac{dQ}{dt} = \frac{\Delta T}{\frac{3x}{KA}} = \frac{(T_2-T_1)KA}{3x}$$

$$= \frac{1}{3}\left\{\frac{A(T_2-T_1)K}{x}\right\} \qquad \therefore f = \frac{1}{3}$$

52. **(d)** Wein's law correctly explains the spectrum

53. **(b)** Heat required for raising the temperature of a body through 1°C is called its thermal capacity.

54. **(b)** Pyrometer is used to detect infra-red radiation.

55. **(a)** Black body is one which absorb all incident radiation. Black board paint is quite approximately equal to black bodies.

56. **(c)** When water is cooled at 0°C to form ice, energy is released from water in the form of heat. As energy is equivalent to mass, therefore, when water is cooled to ice, its mass decreases.

57. **(a)** From stefan's law, the energy radiated per second is given by $E = e\sigma T^4 A$

Here, T = temperature of the body

A = surface area of the body

For same material e is same. σ is stefan's constant

Let T_1 and T_2 be the temperature of two spheres. A_1 and A_2 be the area of two spheres.

$$\therefore \quad \frac{E_1}{E_2} = \frac{T_1^4 A_1}{T_2^4 A_2} = \frac{T_1^4 4\pi r_1^2}{T_2^4 4\pi r_2^2}$$

$$= \frac{(4000)^4 \times 1^2}{(2000)^4 \times 4^2} = \frac{1}{1}$$

58. **(b)** From Newton's Law of cooling,

$$\frac{T_1 - T_2}{t} = K\left[\frac{T_1 + T_2}{2} - T_0\right]$$

Here, $T_1 = 50°C$, $T_2 = 40°C$

an d $T_o = 20°C$, $t = 600S = 5$ minutes

$$\Rightarrow \frac{50-40}{5\,\text{Min}} = K\left(\frac{50+40}{2} - 20\right) \quad \text{...(i)}$$

Let T be the temperature of sphere after next 5 minutes. Then

$$\frac{40-T}{5} = K\left(\frac{40+T}{2} - 20\right) \quad \text{...(ii)}$$

Dividing eqn. (ii) by (i), we get

$$\frac{40-T}{10} = \frac{40+T-40}{50+40-40} = \frac{T}{50}$$

$$\Rightarrow 40 - T = \frac{T}{5} \Rightarrow 200 - 5T = T$$

$$\therefore T = \frac{200}{6} = 33.3°C$$

59. **(b)** Rate of Heat loss $= mS\left(\frac{dT}{dt}\right) = e\sigma AT^4$

$$-\frac{dT}{dt} = \frac{e\sigma \times A \times T^4}{\rho \times Vol. \times S} \Rightarrow -\frac{dT}{dt} \propto \frac{1}{\rho S}$$

$$\frac{\left(-\frac{dT}{dt}\right)_A}{\left(-\frac{dT}{dt}\right)_B} = \frac{\rho_B}{\rho_A} \times \frac{S_B}{S_A} = \frac{10^3}{8 \times 10^2} \times \frac{4000}{2000}$$

$$\Rightarrow \left(-\frac{dT}{dt}\right)_A > \left(-\frac{dT}{dt}\right)_B$$

So, A cools down at faster rate.

60. **(a)** According to Newton's law of cooling,

$$\left(\frac{\theta_1 - \theta_2}{t}\right) = K\left(\frac{\theta_1 + \theta_2}{2} - \theta_0\right)$$

$$\left(\frac{60-50}{10}\right) = K\left(\frac{60+50}{2} - 25\right) \quad \text{..... (i)}$$

and, $$\left(\frac{50-\theta}{10}\right) = K\left(\frac{50+\theta}{2} - 25\right) \quad \text{..... (ii)}$$

Dividing eq. (i) by (ii),

$$\frac{10}{(50-\theta)} = \frac{60}{\theta} \Rightarrow \theta = 42.85°C \cong 43°C$$

61. **(b)** By Newton's law of cooling

$$\frac{\theta_1 - \theta_2}{t} = -K\left[\frac{\theta_1 + \theta_2}{2} - \theta_0\right]$$

where θ_0 is the temperature of surrounding.

Now, hot water cools from 60°C to 50°C in 10 minutes,

$$\frac{60-50}{10} = -K\left[\frac{60+50}{2} - \theta_0\right] \quad \text{...(i)}$$

Again, it cools from 50°C to 42°C in next 10 minutes.

$$\frac{50-42}{10} = -K\left[\frac{50+42}{2} - \theta_0\right] \quad \text{...(ii)}$$

Dividing equations (i) by (ii) we get

$$\frac{1}{0.8} = \frac{55 - \theta_0}{46 - \theta_0}$$

$$\frac{10}{8} = \frac{55 - \theta_0}{46 - \theta_0}$$

$$460 - 10\theta_0 = 440 - 8\theta_0$$

$$2\theta_0 = 20$$

$$\theta_0 = 10°C$$

62. **(b)** From Newton's law of cooling,

$$t = \frac{1}{k}\log_e\left(\frac{\theta_2 - \theta_0}{\theta_1 - \theta_0}\right)$$

From question and above equation,

$$5 = \frac{1}{k}\log_e\frac{(40-30)}{(80-30)} \qquad ...(1)$$

$$\text{And, } t = \frac{1}{k}\log_e\frac{(32-30)}{(62-30)} \qquad ...(2)$$

Dividing equation (2) by (1),

$$\frac{t}{5} = \frac{\frac{1}{k}\log_e\frac{(32-30)}{(62-30)}}{\frac{1}{k}\log_e\frac{(40-30)}{(80-30)}}$$

On solving we get, time taken to cool down from 62°C to 32°C, $t = 8.6$ minutes.

63. **(c)** According to Newton's law of cooling, the temperature goes on decreasing with time non-linearly.

64. **(a)** According to newton's law of cooling

$$\frac{d\theta}{dt} = -k(\theta - \theta_0)$$

$$\Rightarrow \frac{d\theta}{(\theta-\theta_0)} = -kdt$$

$$\Rightarrow \int_{\theta_0}^{\theta}\frac{d\theta}{(\theta-\theta_0)} = -k\int_{0}^{t}dt$$

$$\Rightarrow \log(\theta-\theta_0) = -kt + c$$

Which represents an equation of straight line.

Thus the option (a) is correct.

65. **(d)** From Newton's law of cooling $-\frac{dQ}{dt} \propto (\Delta\theta)$